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The Black Duck in the Chesapeake Bay of Maryland: Breeding Behavior and Biology

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ABSTRACT

The breeding behavior and biology of black ducks, *Anas rubripes*, were observed from 1953-1958 on the upper Eastern Shore of Chesapeake Bay in Maryland. Ducks were trapped, banded and marked during the study in an essentially estuarine habitat, which was frost-free from mid-April to early November. The general habitat adjoining the Bay consisted of cultivated fields, pine woods with dense underbrush, extensive marshes in some areas, and duck blinds.

Resident black ducks began to pair in the late summer and reached a peak in early April just before the height of the breeding season. Few if any young were observed to pair in the early fall. In the spring the male defended a territory for each clutch, generally using some promontory along the shore. The male remained nearby while the female built her nest, gradually deserting his mate during incubation. Eventually the pairing bond disappeared, although some males probably paired again with renesting hens.

Females renested one or more times when the eggs were destroyed or even when the ducklings disappeared on the first day after hatching. At least eight out of 51 marked ducks were known to have renested.

The dates of first laying varied from March 9 to March 27. The nesting peaks occurred about April 20. The first hatching occurred in early April; the last in early August. The date by which 50 percent of the nests were started was significantly earlier in 1953 than in 1957 or 1958 but no other differences were significant. Comparison of the peaks of hatching and of laying showed that in 1958 a loss of early clutches occurred.

Nests were built most extensively in woods, less so in fields and marshes and markedly on duck blinds. They were constructed from adjacent material (leaves, grass, twigs, pine needles) in shallow basins, which were occasionally used by renesting females. Usually the nest site was covered by honeysuckle, poison ivy, brush, or grasses. Spacing between nests was determined by available cover; sometimes they were placed within a few feet of each other. The density varied from 0.6 to 15.2 nests per acre.

The average number of eggs in a clutch declined from 10.9 to 7.5 during the season (360 clutches). Young females laid smaller average clutches (9.2) than adults (9.7). Primary clutches were larger (9.1) than secondary clutches (8.1) for the same females. The incubation period averaged 26.2 days (51 clutches). Neither size of clutch nor season had a significant effect on incubation period. About 5.6 percent of the eggs did not hatch.

The fate of nesting was determined for 574 nests. During the six years, 38.0 percent hatched at least one egg, 11.5 percent were abandoned, and 50.0 percent were destroyed (34.0 percent by crows). Although complete and incomplete clutches were equally susceptible to predation, over half (51.8 percent) of the destruction of complete clutches occurred in the first week of incubation. An average of 9.6 percent of eggs in successful clutches was taken by crows.

Estimations of production indicated that 100 females would raise 510 young to flying age and that the population in the area would decline if the mortality rate of females from flying age to breeding exceeded 78 percent.

Introduction

This report describes detailed observations for several consecutive years on the breeding behavior and biology of a population of black ducks in a small area. The habitat and population density of black ducks permits familiarity with the birds and an unusual opportunity for research. Some specific questions were asked: When do black ducks pair? How long do they remain together as pairs? Is the decline in clutch-size with season related to reneating, to age of female, or to some habitat aspect? How many ducklings does the average female produce? Some data have already been presented concerning incubation, hatching, reneating and productivity (Stotts, 1956), pairing (Stotts, 1958A), and unusual nesting sites (Stotts, 1958B).

The black duck ranges throughout the eastern United States and eastern Canada. Most of the population is migratory, breeding in a block primarily from North Carolina northwestward to Hudson Bay and eastward to the Atlantic Ocean and wintering primarily from the Mississippi River Basin and the Great Lakes to the Atlantic Ocean and northeastward into the Maritime Provinces (Stewart, 1958). Stewart indicates that the highest population densities of wintering black ducks are found in the tidewater areas of the Middle Atlantic States, particularly in Maryland. Additional information on the distribution of black ducks in Maryland is presented by Stewart and Robbins (1957).

The number of breeding black ducks in the area is large but estimates are difficult. The available information is presented in a separate report (Stotts, 1959). For example, the latter report shows that during the height of the nesting season on the study area, an estimate of 17 birds per mile of shoreline was observed. Certainly hundreds of birds nested in the region. The migrants from the north began to arrive in late September and to leave in late February.

The study had its inception when the junior author made observations in the area in 1951-52 that indicated studies of breeding biology of the black duck would be fruitful. In March 1953, the senior author began intensive work that continued

throughout each breeding season, except in 1955, up through 1958.

These studies have received support from many agencies and persons. The Maryland Game and Inland Fish Commission gave primary support with Federal Aid to Wildlife Restoration funds under Pittman-Robertson Project Number W-30-R. The Division of Vertebrate Ecology of the Johns Hopkins School of Hygiene and Public Health gave partial support in 1953 and 1955.

Numerous persons assisted at various times. William R. Nicholson helped collect data and assisted with the initial investigation. Joe Usilton facilitated work on Parsons Island, as did the corporate owners of Bodkin Island. Robert E. Stewart, R. V. Truitt, and Charles S. Kendeigh made helpful suggestions. Assistance with field work was given by Richard N. Smith, Charles L. Hanson, and Gerald F. Young. We also appreciate editorial assistance from personnel of the Maryland Department of Research and Education and U. S. Bureau of Sports Fisheries and Wildlife.

METHODS

The investigative approach has been described in four earlier papers (Stotts, 1956, 1958A, 1958B, 1959). Essentially it consisted of the following major methods: (a) observations on the breeding behavior were facilitated in nearly all months of the year with the aid of binoculars, bands, paints and traps; (b) further observations were augmented by foot and boat patrols, at vantage points, and by flushing birds from nests; (c) sexes were identified by differences in physical appearance, primarily coloration of legs, head region and bill, and by voice; (d) birds were aged by cloacal methods (Kortright, 1943) or presence of known age bands for birds in adult plumage and by plumage stages and fingerling fish tags (Gollop and Marshall, 1954; Stotts, 1959); (e) nests were found by systematic search, varying in intensity with cover types, through likely breeding areas, duck blinds, grackle nests and heron nests; (f) nests were marked with branches cut from nearby shrubs, stakes or green shipping tags depending upon the

habitat types; (g) nest numbers and, whenever possible, the series in the clutch was inscribed on eggs with a hard lead pencil; (h) data were taken at each nest, with subsequent recapitulation on each visit, consisting of time of day, precise location, presence of female, number of eggs, whether nest covered or not, presence of male, habitat, basic cover, amount of down, stage of laying or incubation, composition of basin material, flushing distance, where female landed, behavior of other ducks to the female, presence of band on legs, and proximity to other nests; (i) all sizes of birds captured were banded or were marked with fingerling fish tags; (j) observational periods were made of nesting females from daylight to several hours after dark, usually from mid-March to late July; (k) females were trapped on the nest using a drop-trap described by SOWLS (1950), with a drawstring arrangement of $2\frac{1}{2}$ inch stretch, heavy grade cotton net, with a deep-bodied, large-hoop dipnet, and with bare hands; (l) nesting females were marked with spray enamel on the upper surfaces of the leading edges of the wings and tail (Fig. 1) and with enamel dripped from a Lunkenheimer oil dripcup (Stotts, 1956).

The intensity of searching for nests was dependent upon the density of cover. For instance, whereas a wooded area could be accurately surveyed for presence of nests by walking 30 foot intervals or more in March and much of April, the intervals were often narrowed to 10 feet or less in May and June when new vegetation gave dense cover. To show the uniformity and intensity of search time per two week period (11 periods) from March 1 to August 1 in 1953-54 and 1956-58 (five years) the following averages (days per 14 day period) have been compiled: 10.4 (March 1-14), 10.4, 9.8, 9.0, 10.0, 12.2 (May 10-23), 10.2, 10.8, 11.2, 8.8, and 9.2 (July 19-August 1). Most observations in the field began by early February when banding operations commenced except in 1953 (March 28).

The statistical methods were relatively conventional. Under the section on egg laying the dates by which 50 percent of the eggs were laid or nests hatched were obtained



Fig. 1.—Black duck females were caught on their nests and marked with spray enamel on the leading edge of the wing to observe renesting behavior.

by plotting the cumulative percentages on arithmetic probability paper and then reading the date at the 50 percent line. This method smooths the data and de-emphasizes extremes at either end. The actual date will differ in some cases from the date determined directly by counting the clutches. Significance was calculated by a simplification of the probit method. For clutch size, significance of differences between means was determined by the use of tables for the *t*-test. The relation of variables of clutch size and season on incubation times was calculated by multiple regression (Snedecor, 1956:413-420).

The Study Area

A small Coastal Plain section of the upper Eastern Shore of Maryland on the Chesapeake Bay, known as the Kent Island area, was the primary region of study (Fig. 2). It is a tidal zone, about 14 miles long and six miles wide, bordered by the Chesapeake Bay and two of the Bay's estuaries, the Eastern Bay and the Chester River. For a distance of one-half mile on its east side, the Island comes within 200 yards of the Eastern Shore mainland.

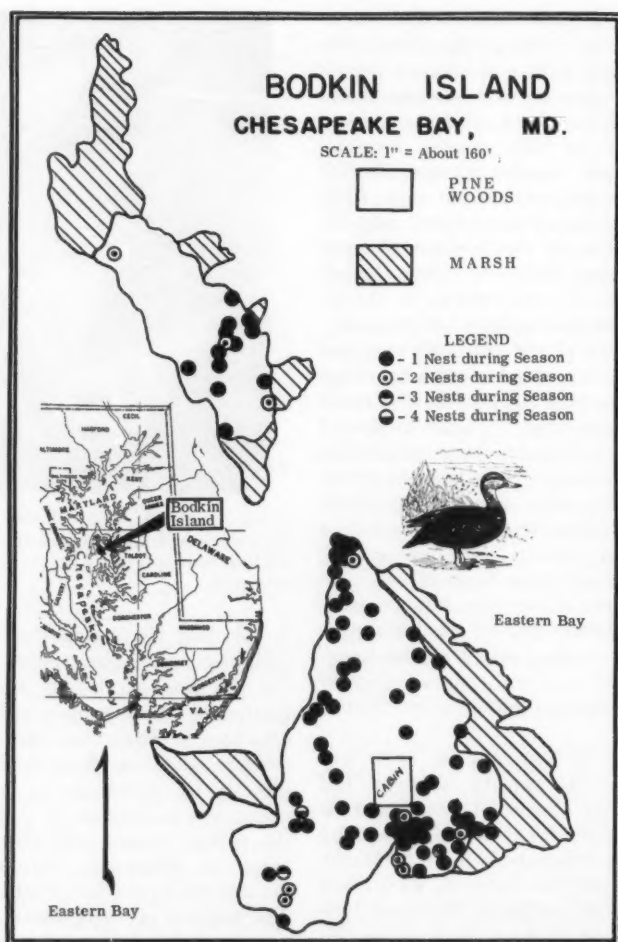


Fig. 2.—Distribution of 106 black duck nests found in 1954 on Bodkin Island, adjacent to Kent Island, Queen Annes County, in Chesapeake Bay, Maryland.

Kent Island is intensively cultivated except for numerous brackish marshes and for woodlands bordering shorelines. Most marshes are small, tidal saltmeadow and saltmarsh cordgrass areas interspersed or bordered by saltgrass, needlerush, wax myrtle, hightide bush, and groundsel bush (see Appendix I for scientific names of plants and animals). Loblolly pine predominates in most woodlands with sparse to medium occurrence of sour and sweetgums, scrub pine, black locust, maples and oaks. The undergrowth

is dominated by honeysuckle, greenbriar, poison ivy and trumpet vine. It should be noted that the loblolly pine and needlerush reach their northernmost point of distribution in Maryland in the region of the study area (Fernald, 1950; Shreve et al., 1910). The former is important to the black duck as nesting habitat and the latter important as brooding and molting cover.

The U. S. Weather Bureau (1954) gave the following climatic statistics for the upper Eastern Shore at Easton: Mean annual

rainfall 43.2 inches; mean annual temperature 55.0°F.; killing frosts end about April 14 and begin about November 1, giving a potential growing season of about 201 days; the advent of spring as indicated by a mean daily temperature of 44 degrees Fahrenheit usually occurs during the last week in March. The prevailing winds are usually northwesterly from October to April, while from May to September they are generally southwesterly.

Salinity of waters adjacent to Kent Island approaches freshness in most spring seasons and increases to about half the strength of sea water (15 ppt) during occasional long, dry summer periods. Generally, salinity averages approximately 30 percent (10 ppt) the strength of sea water according to salinity samples collected by Dr. R. V. Truitt of Kent Island and processed by the Chesapeake Bay Institute of the Johns Hopkins University. Winds sometimes cause severe fluctuations in water levels but generally tidal amplitude varies about 1.0 to 1.5 feet.

Extending outward from most of Kent Island's shorelines are extensive shoals covered with dense beds of submerged, brackish water plants, many of which extend to the upper reaches of the many tidal creeks. Eelgrass, widgeongrass, sago pondweed, claspingleaf pondweed, southern naiad, horned pondweed, elodea and sea lettuce are common depending upon water depth, substratum, and tidal and wave actions.

Merging with the shoals extending from points of land on the south side of Kent Island are the extensively vegetated shoals of Parsons Island, Bodkin Island and Long Marsh Island. These islands were the specific areas of the nesting study. Parsons Island consists of 130 acres with a shoreline of about 2.6 miles. Until 1957, approximately 70 acres were intensively cultivated. Five patches of marsh totalling 18 acres were present. The rest of the acreage is in mixed woody growth, dominated by loblolly pine and hardwoods. Bodkin Island was five acres in size in 1953 with a shoreline of about 0.8 miles. Through the effects of erosion, the island has been divided by shallow water 100 yards wide. Erosion is continuing rapidly to destroy the loblolly pines growing

above a six to eight foot bank. Very little marsh exists now.

Two areas adjacent to the small islands on Kent Island were less intensively studied during the nesting seasons. Normans and Narrow Points, near Parsons Island, were primarily marsh with a shoreline of 2.4 miles, while Turkey point, near Bodkin and Long Marsh Islands, was primarily under cultivation. Exactly one mile of shoreline was under observation in the latter area.

In addition to the above-mentioned places, occasional observations were made of nesting and brooding ducks on small marshes and wooded areas throughout the Kent Island area and the adjacent mainland. Duck blinds throughout most of the state were subsequently searched for evidence of nesting.

Breeding Behavior

Some behaviorisms shown between individuals or groups within an animal species are instrumental in determining population densities during specific seasons. Other behaviorisms may affect the breeding success of a species or population. While closely allied bird species, such as the black duck and mallard, may affect each other's range of activities, usually competition within a species for space, food, cover and breeding partners determine the species' daily and seasonal habits.

THE FORMATION OF PAIRS

A first step in the understanding of the breeding biology is to determine when pairing occurs among the various sex and age classes of the black duck (Stotts, 1958A). From February 11 to March 10, when a few nests were begun, paired birds made up 50 percent of the total counts (Table 1). As nesting activity reached its peak in late April, about 90 percent of the birds in counts were paired. By early July, when the last nests were begun, pair counts fell to about six percent.

The lowest level of birds seen as pairs (three percent) was found in early August when somewhat over half the adult males and less than half of the adult females had completed the postnuptial molt. There was

TABLE 1.—Numbers and classes of black ducks seen during shoreline surveys by boat in the Kent Island area, 1956–57.¹

Four-week Period	Number in Doubles	Number in Singles	Number in Flocks	Total Number	Percent in Doubles	
					Observed	Corrected ²
Feb. 11–Mar. 10	88	0	88	176	50.0	50.0
Mar. 11–Apr. 7	330	18	246	594	55.6	58.6
Apr. 8–May 5	832	263	152	1,247	66.8	87.8
May 6–June 2	672	281	216	1,169	65.5	73.5
June 3–June 30	370	206	1,753	2,329	17.9	18.8
July 1–July 28	126	193	1,965	2,284	5.5	5.5
July 29–Aug. 25	194	247	6,072	6,513	3.0	3.0
Aug. 26–Sept. 22	506	238	8,355	9,099	5.6	5.6
Sept. 23–Oct. 20	914	156	7,726	8,796	10.4	10.4
Oct. 21–Nov. 17	116	13	639	768	15.1	15.1

¹ The following classes were not included: ducks in banding traps, ducks in flocks larger than 100 birds, females on nests, females with broods, and flightless young.

² Singles were considered to be wholly paired March 11–May 5, two-thirds paired May 6–June 2, one-third paired June 3–June 30, and not paired before and after these periods.

some increase in number of paired birds during September and then once again pairs became very evident.

To examine directly the composition of the pairs, 13 individuals from 10 black duck pairs were collected in November 1957. The sex and age composition of these individuals were as follows: (a) males, adults—7 birds, immatures—0 and unknowns (not collected)—3; and (b) females, adults—5, immatures—1, and unknowns—4. Autopsy of three complete sets of paired birds showed all six birds to be adult. Five had been banded and of these, four were definitely resident breeding birds in 1957. The age composition of the other seven birds collected on later dates, none of which were collected together as a pair, was adult except for one female shot on November 22.

The evidence, thus, is that: (1) percent of paired birds began to rise in late August and early September, at a time when (2) all mating bonds for the current breeding season had been broken, when (3) the majority of the adult birds had completed the post-nuptial molt, and when (4) the very oldest juvenile birds were about four months old and were judged to be sexually too immature to complete a pairing bond. At that time and probably up through much of November, it is believed that paired black ducks were primarily adults. It seems likely that juvenile females begin to pair by the

age of six to seven months with juvenile males lagging behind one or two months. Information presented elsewhere (Stotts, 1959), however, indicates the presence of non-breeders in the population. Thus, considering these time factors and the usually greater numbers of juveniles, the majority of the pairing in black ducks must occur when juvenile males become available for pairing in December and January. Since adults are apt to be paired first, with perhaps many setbacks caused by the mortality of one or both of the pair during hunting, a basis is seen for earlier nesting by adult birds. Adults are paired first and therefore reach breeding tempo before the young birds which are nesting for the first time.

Johnsgard (1960:136) estimated that frequency of pairing in the black duck studied in New York rose sharply from about November 1 to a leveling plateau about February 1. He indicated that pairing prior to November 1 appeared to be of a temporary nature. Ramsay (1956) also indicated that frequency of display involved in courtship and pairing of Maryland black duck reached its peak in December and January.

Only three cases of courtship were noted during and after the breeding season. A marked female which had had her nest destroyed several days before was observed leading two males with incessant quacking while flying at full speed on May 11, 1954.

A similar incident was noted on May 9, 1956. An obviously paired black duck couple was noted in "head-pumping" display on November 9, 1957 but copulation did not take place. Although black ducks were not noted in copulation (see exception on p. 137), mallards were noted in apparent copulation several times from November through February.

BREAKING THE PAIRED BOND

In many species of waterfowl the male leaves the female within a few days after the hen begins to incubate (Hochbaum, 1944). Shovelers and blue-winged teal, however, often remain in attendance throughout much of the incubating period and may even help with brooding duties (Girard, 1939; Sowls, 1955). From observations on the study area, the length of time the black duck male remained with the female after initiation of incubation appeared to be dependent on both the individual and the period of the season when the nest was begun. Records of minimum periods which males remained after incubation began were obtained on 15 males during the 1954 breeding season. Based on the nesting peak which occurred about the first week in May, the nesting season was divided into two segments; nests begun prior to and during the first week in May were considered to be mainly primary nests, although much renesting, no doubt, occurred during this period. Those nests begun following this period were considered to be primarily, if not wholly, renests. Seven examples of male attendance after incubation began averaged a minimum of 14.3 days with a range from 7 to 22 days for the primary nesting period. Minimum attendance during the renesting period averaged 9.1 days for 8 examples ranging from minus 4 to 16 days.

These data indicate that the individual male tended to remain longer during the first nesting attempt than during renesting. Males breeding for the first time with a renesting female may also remain longer than do males that are renesting. Males at the extreme end of the nesting season may leave before the female has completed her clutch.

From several observations it appeared that in some cases, the female deserted the

male. For instance, two females were noted to elude attentions of their apparent mates 22 and 19 days after incubation began during the primary nesting period. During the renesting period females were seen eluding the attention of their probable mates after 6, 9, and 12 days incubating. In four of the observations the female exhibited antagonism toward the respective male. Trautman (1949) noted similar incidents in the black duck in Ohio.

From these observations, it became apparent that the role of the unmated males in the annual breeding cycle may not be as important in the black duck as in some waterfowl species where the males leave soon after incubation begins. Sowls (1955) has pointed out the importance of unmated males to renesting for some species in the Canadian provinces. In the black duck, the presence of unmated males may not be important until the second renesting attempt, since the primary males, in most instances, were still present through the period when the first nest was likely to be destroyed.

TERRITORIAL BEHAVIOR

Males of many species of ducks are known to defend a small area that appears to ensure successful copulation or at least pairing. For our purposes territorial behavior is defined as an act of aggression by a black duck male (alone or attended by a female) toward intruding members of the species concerning a small area from which the male may vacate during the aggressive act but to which he immediately returns upon completion of the act.

Three separate types of territorial defense were noted: (1) threat indicated by head-bobbing and "quibbling" notes, (2) threat posture with neck outstretched parallel to the water while swimming toward the intruder and often resulting in aerial pursuit for not more than one-half mile, and (3) actual contact sometimes involving flight. Display involving aerial pursuit without contact accounted for over three-fourths of the observed displays. The number of incidents by types of display were as follows: (a) aerial pursuit without contact—39 inci-

TABLE 2.—Frequency and relationships of territorial display by male black ducks in the Kent Island area, 1953-1958.

Two-week Period	Defense Relationship ¹									Total	
	Lone male defense against					Attended male defense against				Number	Percent
	Male	Fe- male	Pair	Trio	Total	Male	Fe- male	Pair	Total		
Mar. 15-Mar. 28	—	—	—	—	0	—	—	1	1	1	2.0
Mar. 29-Apr. 11	1	—	3	—	4	1	—	1	2	6	12.0
Apr. 12-Apr. 25	—	—	4	—	4	1	—	—	1	5	10.0
Apr. 26-May 9	—	3	11	2	16	—	—	1	1	17	34.0
May 10-May 23	2	1	6	1	10	—	2	2	4	14	28.0
May 24-June 6	—	—	1	—	1	1	1	1	3	4	8.0
June 7-June 20	—	—	1	—	1	—	—	—	0	1	2.0
June 21-July 4	—	—	1	—	1	1	—	—	1	2	2.0
Total	3	4	27	3	37	4	3	6	13	50	100.0
Percent	6.0	8.0	54.0	6.0	74.0	8.0	6.0	12.0	26.0	100.0	

¹ Defending males were paired in all cases. The "lone" male was at a site awaiting his mate's return whereas the "attended" male was in his mate's company.

dents (78 percent); (b) swimming toward intruder with neck outstretched, without contact—7 (14); (c) aerial pursuit with contact—2 (4); (d) head-bobbing—1 (2); and swimming toward intruder with neck outstretched, with contact—1 (2). Females were never observed defending although some closely followed their drakes as they displayed.

A total of 50 incidents involving territorial behavior were noted; five in 1953, 20 in 1954, eight in 1956, 10 in 1957, and seven in 1958 (Table 2). The highest frequency of antagonism occurred during the period from April 26 to May 23 with 9, 8, 9, and 5 incidents in each respective week. This four-week interval was the period when the greatest amount of renesting was in progress.

The greatest frequency of antagonism occurred between lone males and intruding pairs. Intrusion into a defended area by pairs evidently was the greatest threat to an unattended male which was awaiting his female's return from the nest. About three-fourths of all defenses were instigated by males unattended by females. One actual physical combat was observed on May 11, 1954. A female was flushed from her nest and flew toward the shoreline 50 yards away. As the observer neared that point, a male flew in from an unknown point up the shoreline. Immediately a male known to loaf at the point while his female was on her nest

drove at the intruder which did not retreat. Without pretense of threat the fight began. Numerous feathers were plucked from the lower back of both birds, although the head was the main point of attack. For a full five minutes no sound was made other than the thrashing of water. Flight was not involved at any time. The resident male finally won; the intruding male merely swam off. The victor then menacingly swam toward a nearby watching pair; they immediately flew off and he returned to his previous site to preen. The losing male had in the meantime swum offshore about 100 yards. On another occasion, an attended male pursued a hen with a brood for a short distance across the water, but left the unconcerned 5-week old brood alone. In contrast to such territorial aggression, a pair once joined a female in feigning behavior when the observer attempted to capture her brood.

The frequency of territorial defense was quite low considering the size of the population, especially on Bodkin Island where as many as 18 pairs and four drakes were present at one time. In countless cases, pairs in close proximity showed no antagonism, although the sudden appearance of a strange bird at the scene might have promoted defensive behavior. For instance, on June 1, 1954, two pairs and a male were noted feeding within 40 yards of each other. There was a slight show of antagonism, which

quickly dissolved, between the male of one pair and the lone male, but they all continued to feed and loaf until 10:40 a.m. Suddenly two pairs appeared from beyond a nearby grove of trees. The same antagonistic paired male immediately pursued them, before they could alight, for several hundred yards and then returned to his mate. The other two males appeared disinterested.

Wright (1948) at first indicated that the black duck in New Brunswick lacked territories. But Mendall (1949) showed that although territorial behavior was not readily apparent on breeding ground surveys, still it played a definite role in the breeding ecology of the black duck in Maine. Wright (1954) later indicated that the New Brunswick black duck may shift its territory due to the fluctuations in water level during the breeding season. However, in four years of observations, he saw very few unquestionable examples of territorial defense.

Territorial sites:—Miscellaneous observations suggested several conclusions concerning the relationships of territorial sites. Generally, a male's favored loafing spot, which in some cases was defended, was a site that had an unrestricted view for some distance in at least one direction along the shoreline. Shoreline grown up to dense plant growth was usually avoided, as were steep banks whose bases were confluent with deep water unless a fallen tree which extended into the water was present. Depth of water at these sites apparently made little difference as long as it was possible for the individual to crawl or fly up on the loafing spot without difficulty. Pairs seemed to pick the more protected south and east shorelines where wave action was slight. Feeding sometimes occurred near the loafing site. Some areas, though, often had large groups of feeding pairs which indicated they were also used as neutral feeding areas. However, two incidents of defending such areas were noted—probably by territorial males resident at these points or by males which were defending their females from excessive attention.

Males or pairs disturbed by the observer usually flew a short distance offshore perpendicular from their site, landed, and

returned soon after the observer withdrew from view.

One marked female was followed through three nesting attempts. A new loafing site was selected for each attempt yet all were within a 300 yard stretch of the shoreline. In another case of two nesting attempts the loafing sites were within 100 yards of each other. However, in four out of five of the above nesting attempts the chosen loafing site was the closest possible distance to the nesting site. This proved true for most nests—the nearest point of water to the nest was often the male's loafing spot while the female was at her nest.

BEHAVIOR OF PAIR DURING NESTING

Before nesting began, females often led their mates in a haphazard manner over suitable nesting habitat. During rainy spells large numbers of non-nesting, but segregated, pairs frequented freshwater puddles in cultivated fields to feed and to loaf. When the time for nesting approached the pair went together in search of suitable nesting habitat. If disturbed during this preliminary search, the pair flew off, the female quacking loudly and was never found to return to that exact area to build a nest. During days when high tides flooded the marshes, the observer regularly heard females quacking incessantly over long periods of time. Such behavior may have indicated that the female's nest had been flooded.

Behavior of males:—Males usually remained at a nearby site when their females began to construct their nests. Sometimes, however, males apparently waited at distant sites since some females flew to points two or three miles away after they were flushed from their nests. The males' sites were often selected after the nesting area had been chosen and therefore were believed to be more the product of the females' choices than of the males'.

After the clutches were begun, the males generally became segregated from their females for increasing periods of time each day. In only five instances were males noted at the nest after laying began. In these cases, the females had been incubating one, two, 11 and 21 days. While the hens were laying, the males rarely went along to the

nest sites but loafed at customary sites on nearby shorelines. They were generally alert, seldom indulging in feeding or dozing until their mates returned. Even then they were the more alert, being the first to sight danger, but usually the last to take flight.

As the females began to increase their incubating activity, the males, also, became less attentive to their mates and eventually deserted their chosen feeding and loafing sites to join other post-breeding males and non-breeding birds. Congregating in regularly inundated marsh areas, these birds then began the postnuptial molt and period of flightlessness and left the incubating females to hatch their clutches and to rear their young.

Behavior of females:—During the nest-building period, females were extremely wary. Often they flushed within 100 yards, depending on the cover, and abandoned the site with loud quacking, usually never to return. Experience indicated that hens did not advertise their presence in the vicinity of their nests unless they were going to desert, they were taken by surprise, or their clutches were ready to hatch. Under these circumstances they quacked loudly as they departed. They invariably quacked if there were no nests.

Most females had a favored exit and approach to their nests. When returning to the nest they walked from about 100 feet, usually using the same route each time. This behavior facilitated discovery of nests on saltmeadow cordgrass marshes and in hayfields—for both observer and predators.

Continual incubation began with the laying of the last egg although some incubation may have occurred before then. Just when the inattentive periods occurred was not determined. Females were found on the nest throughout the daylight hours and after dark. Two were noted shading their eggs from direct sunlight on extremely hot days.

As laying and incubation progressed, females spent more and more time at their nests. The flushing distances tended to become progressively shorter, flights from the nest became progressively slower, and the distance they flew before landing always

became shorter. In flight, they tended to remain near ground level and to quack only after flying about 100 yards from their nests. This quack was typically more subdued than their normal alarm call. At the time the eggs were being pipped, females remained at the nests almost continuously and would not flush until danger was very near, sometimes not until they were stepped on. They then flushed in a hesitant manner, taking short fluttery flights, and exhibited the broken-wing behavior.

When flushed within sight of the observer females seldom covered their eggs. As they flew, they would frequently defecate a foul-smelling watery liquid, usually brown or olive-drab in color. As incubation proceeded, the defecating behavior became more frequent. When the hens flushed at long range they seldom defecated; at short range they almost always did. Wright (1954) believes defecation by the hen "... may be due to fright, or it may be a deliberate attempt to camouflage eggs, which she has not had time to cover." Fright appears to be a prime factor but defecation more often appears to be deliberate. Besides possibly camouflaging the eggs, the pungent odor of the fluid may be repellent to some potential predators. The fluid may also be distasteful and prevent the eggs from being eaten.

As females continued to incubate, their appearance changed; the bill became almost black, the cheeks appeared darker, the legs became darker, and the lores often took on a whitish or rusty appearance. Molted feathers were seldom found at the nest, since general body-feather molting was slight until after the female's clutch had hatched.

MALE PROMISCUITY

On 12 occasions, when black duck females were flushed from the nest they were pursued by, apparently, strange males. In two cases only one male pursued, in six cases two males pursued, in two cases three males pursued, and in two cases four males chased the female. According to Höhn (1947) single or grouped, mated or unmated male mallards will copulate with females coming off the nest in the early part of the breeding season.

Black duck females were seen forced to

the water in only two cases. In one instance, the female was pursued by two males as she dodged and twisted in flight. About two miles from the nest site, she was forced to the water and out of sight of the observer. In the second case a female which had incubated about 16 days was pursued by four males until she lit on the water. Three of the males immediately copulated with her. A few minutes later the female flew away with one of the males. In several instances females flushed from the nest were pursued by males over a dodging course of flight until all were out of sight more than two miles away.

In several other instances, females were pursued by strange males until the female's apparent mate appeared. For example, a female was pursued by four males but she landed under her own volition after a one-fourth mile, straight-line flight. After all birds had landed there was some evidence of further pursuit, but one male appeared to be favored. The remaining males hung back about 30 yards.

Grouped males did not always respond sexually to the sight and sound of females that were flushed from nests. Lone males were observed coming from groups of three to six males to join females which had been flushed from their nests. In these cases, the lone male appeared to be the female's rightful mate. In one instance, a female flushed from her nest was joined immediately by a male from a group of four. A few minutes later one of the remaining three males joined another female which was scared from her nest.

RENESTING BEHAVIOR

Some birds may produce two or more broods a year. Such birds have "first nests", "second nests" and so forth, and they may also have several "renests" before successfully concluding one nest or brood. The whole process of nesting is accelerated; fewer eggs are laid, incubation time is shorter, and the young attain self-reliance sooner. In most ducks, however, the whole process of breeding and brooding spans a period of about 98 days; about 12 days for nest building and egg laying, about 26 days

for incubation, and about 60 days to raise the brood to flight status. Thus, it is seen that there is insufficient time for a duck to begin and complete a "second nest" or to produce a second brood.

The first comprehensive study of renesting behavior was done by Sowls (1950, 1955). Other studies had suggested the importance of renesting to annual waterfowl production but only a few observations (Barnes, 1948; Engeling, 1949) had actually proven that individual birds did renest. Sowls' (1955) studies are much more extensive and give information for several puddle duck species such as renesting clutch sizes, intervals between primary and secondary nests, distances traveled between nests, and persistence in renesting.

In 1954, 43 black duck females were caught and marked during the breeding period. One hen was later killed by a raccoon and one was allowed to hatch her eggs. The rest either deserted their nests, lost their clutches by flooding or to predators or investigators. Of the 41 potential renesters, six were found to renest, one twice. All six renesting females were marked on what was believed to be their primary clutches; however, some females marked after mid-April, could have conceivably been renesting.

In 1956, 22 nesting females were trapped on their nests and marked, but in only two instances were females purposely disturbed to disrupt their normal routine. Of the 22 marked females, six deserted due to flooding or observer interference, one lost her nest to crows, and 13 hatched clutches successfully. One female's clutch was collected during the pipping stage, and one brood was taken as they were ready to leave the nest. Since 13 females were successful, there remained only nine potential renesters in 1956. One of these, the female from which the brood was collected, renested. In addition, one of the females which was seen with her brood a half-hour after leaving her nest was found later on another nest.

The six females marked in 1954, whose primary clutches were destroyed before hatching, incubated these clutches an average of about 15 days with a range of 8 to 19 days before their destruction. The two fe-

males (marked in 1956) with successful primary clutches incubated an average of about 28 days. There was no noticeable difference between the renesting intervals of the two successful and the six unsuccessful marked females; the average interval was about 18 days (ranging from 13 to 26 days).

Discounting the other 12 marked females that brought off broods successfully in 1956, eight, or 15.7 percent of the 51 potential renesters marked during the two years were found on new nests.

One female that deserted her second clutch after incubating two days was seen 15 days later and 26 days later (July 10), so it is doubtful that she renested a third time. Three of the other five females that were found on new nests, probably did not renest a second time judging from their behavior following desertion of their new nests. Two females which deserted their renests were not observed following their departure from their nesting sites. Two females produced successful broods on their secondary nests.

From observations of the other 43 unsuccessful females that were marked, and that were not found on new nests it appeared probable that 13 renested elsewhere, that 16 were borderline cases which may have renested, and that 14 did not attempt re-nesting activities. Without a doubt, many of these females were renesting when they were trapped and marked. Twenty-six of the females began their clutches after the first week in May which was believed to be about the point at which all subsequent clutches were renests. If this is true, then a minimum of 41 percent of the 1953 nests, 29 percent of the 1954 nests, and 38 percent of the 1956 nests were renests.

The availability of breeding males may limit further renesting each season. For instance, in 1954, males in flocks became common by May 19. During summer trapping operations only three males in breeding plumage were captured after June 29, and the last male in breeding plumage was caught on July 16. It seems significant that in 1954 only four clutches were found which were started after June 21 and that none were found which were started after July 4.

Black ducks will probably renest several

times if their clutches are destroyed while the hen is laying or within a day or two after incubation begins. Since many of the clutches found on the study area were begun near mid-June or later, two months after the nesting peak, it can be assumed that the ability to renest is probably a result of many factors such as the individual female's physiology, the history of the past nesting attempt, the age of the female, and the availability of breeding males. Evidently, some factor results in the cessation of nesting attempts about July 1.

Nesting Habitat

The available nesting habitat on the study area may be divided into three categories; upland woods and fields, marshes, and duck blinds. About 65 percent of the black duck nests were found in upland areas, about 17 percent in marshes, and about 19 percent in duck blinds (Fig. 3). The preponderance of sites in wooded areas (59.5 percent) may not be a true representation of the Kent Island area as a whole or of breeding preferences since the amount of time searching was not proportional to extent of area and the extent of area was not standardized. For example, a large amount of time was spent in wooded areas and their extent is much greater than the area of marshes.

Wooded areas tended to afford greater cover and isolation during the early part of the nesting season. Fig. 4 shows typical pine habitat which afforded numerous nesting sites resulting from fallen trees and brush heaps. Even intensive grazing in wooded areas could not destroy excellent nesting cover near vine-entangled trees or in brush piles. Therefore, wooded areas were the most important habitat from the standpoint of breeding success early in the season.

On the lower Eastern Shore of Maryland black ducks generally nested at the marsh-upland edges in the open tidal marsh area according to Van Huizen (1932). William Nicholson and Robert Stewart, however, verbally told the authors that they found many nests in the open marsh in 1954. It is our opinion that estimating numbers of nests is much less accurate in marshes than in upland since destroyed sites are more

difficult to find. Clutches abandoned by females because of flooding are found only by chance. Because of the additional hazard to nesting caused by flooding in marshes, annual success may actually be increased if the areas subject to spring flood tides are burned to disperse nesting to more likely habitats before flooding begins. By early May when spring flood tides have begun to abate new marsh vegetation becomes available for renesting efforts.

In addition to normal ground nesting in upland and marshes, black ducks nested in rather odd habitats. One site was found beside a house tenanted on weekends. The female brought off a brood successfully. Four other sites were located in trees, one in an old common grackle nest located 12 feet above the ground and three were in aban-

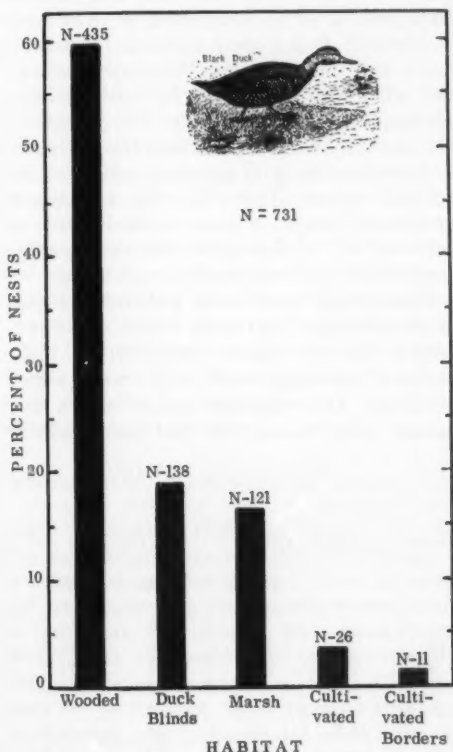


Fig. 3.—Basic habitat types used for nesting by black ducks as observed throughout Chesapeake Bay, 1953–58.



Fig. 4.—Typical pine woods habitat on Bodkin Island used extensively by nesting black ducks early in the breeding season.



Fig. 5.—Nest of a black duck in loblolly pine brushing (camouflage) from the roof of an offshore duck blind in the Chesapeake Bay.

doned nests of great blue herons 70 to 90 feet above the ground in loblolly pines.

Chance discovery of two black duck nests in offshore duck blinds in 1954 led to further studies which uncovered an additional 173 in these structures during subsequent years. In all, 138 black duck nests, 27 mallard nests, and 10 unidentified (black duck or mallard) nests were found in blinds. Fig. 5 shows a typical nest site on the roof of a duck blind. The use of blinds was related to the condition of the nearby shore (Stotts 1958B). A significant preference for nesting was found in blinds located off cultivated lands and housing areas as opposed to blinds located off marshes and wooded areas. The latter habitats apparently afforded sufficient cover and isolation. A significant preference was also found in blinds located off high eroding banks that did not afford nesting cover. Of the blinds with suitable cover, about 10 percent held nests.

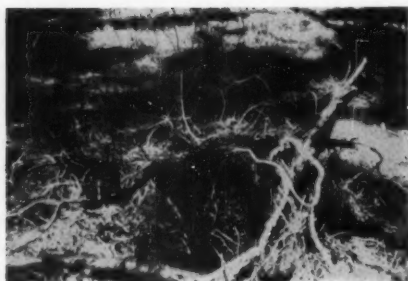


Fig. 6.—Nest of a black duck in a brush pile in a pine woods on Parsons Island.

Most of the clutches found in croplands were believed to be renests. They were begun after new plant growth was of sufficient height to afford good concealment. Most of them, however, were destroyed by man's activities. Nevertheless, those in idle croplands and abandoned borderlands were important since they dispersed some from more intensely used nesting areas.

NESTING COVER

Of the 435 black duck nests found in wooded areas, the majority were in honeysuckle and poison ivy tangles (Table 3). Honeysuckle was the most important cover in wooded areas early in the season when new growth had not begun. Brush piles and the vine-tangled bases of trees also gave good cover early in the season (Fig. 6). Many early clutches located near exposed tree bases, however, were very susceptible to detection by crows.

The great majority of the 121 clutches

found on marshes were in marsh grasses (*Spartina*, *Panicum*, and *Distichlis*). Salt-meadow cordgrass was by far the most important cover involved. Sites in dense needlerush or shrub-growth were located near the periphery of the growth in relation to the well-known "edge-effect" (Leopold, 1933). More nests were found in marshes by the investigator as the seasons advanced. However, the fact that fewer tides flooded the marshes late in the season made nesting sites more available for detection over a longer interval.

Ducks nesting in blinds had a significant preference for cedar or grass-covered types (Stotts 1958B). Apparent reasons for female preference of cedar blinds was that cedar needles lasted longer and, also, even the needleless cedar branches afforded greater cover than needleless pine branches. Nearly 70 percent of all nests on blinds were located on the roof. Cedar always afforded excellent cover for this position. Grasses, however, did not afford any cover for roof nesting. Nesting in grass-covered blinds occurred on the roof only when some added feature, such as a roof-overhang or an extra cedar branch afforded cover. Therefore, the significant preference found for grass-covered blinds is believed to be unrelated to the specific major blind material used for camouflage.

Renesting cover and habitat:—Eight marked females that were found on known renests did not appear restrictive in their choice of renesting cover where a variety was available. One marked female which renested twice located her first nest under a

TABLE 3.—Basic nesting cover of black duck nests within habitat types observed in the Chesapeake Bay, 1953-1958.

Basic Cover	Percent of Nests in Basic Land Habitat Types				Total Nests	
	Wooded	Marsh	Cultivated	Borders	Number	Percent
Tree trunk or stump.....	20.4	—	—	9.1	90	15.2
Brush pile.....	21.6	3.3	—	18.2	100	16.9
Honeysuckle and poison ivy.....	57.9	0.0	3.8	36.4	257	43.3
Marsh grasses.....	—	68.6	—	—	83	14.0
Needlerush and three-squares.....	—	11.6	—	—	14	2.4
Small grain and hay.....	—	—	96.2	—	25	4.2
Marsh shrubs.....	—	16.5	—	18.2	22	3.7
Other.....	0.0	0.0	0.0	18.2	2	0.3
Number of nests.....	435	121	26	11	593	100.0

honeysuckle tangle in a hardwood grove, her second in a brush pile in a hardwood grove and her third in a red clover field. Another marked female laid her first clutch in a barley field and her new clutch in blackberry brambles in a hardwood grove. Six other marked females used quite identical cover for both first and second nests. Although the females may not be restrictive in their choice of renesting cover, they were quite specific in their choice of renesting habitat. All nested and renested in upland habitat. However, the sample is quite small and hardly random.

DISTANCES OF NESTS FROM WATER

The clutches on Bodkin Island (5 acres) in 1953 were situated from eight inches to 112 feet from water, but the latter distance was about the maximum distance possible due to the size and shape of the island. The average for 76 sites was 37 feet. Those on Parsons Island (130 acres) during the same year ranged from 19 to 555 feet with an average of 194 feet for 71 nests. Maximum possible distance from water here was about 950 feet. The nests on Kent Island proper ranged from 10 to 300 feet from water with an average of 71 feet for 12 nesting sites. Numerous studies have shown that waterfowl rarely nest long distances from water, usually averaging less than 150 feet. It is apparent that the distance of the site from water for black ducks in Maryland was not a vital factor. The site was selected on the basis of available cover; if the site was near water so much the better.

NEST CONSTRUCTION

In their primary nesting, black ducks began to construct their nest basins three or four days before eggs were laid. For instance at 1:30 PM on March 29, 1954 an incomplete structure with sides loosely formed and bottom bare was found. The female was absent, but the basin was nicely covered although devoid of eggs. At 12:15 PM on April 4, there were three eggs. Assuming that one egg was laid each day as in normal laying procedure, the female began laying on April 2, or at least four days after formation of the basin.

Females normally dug, with both the feet and bill, a bowl below the base of the surrounding habitat. Only in cultivated areas where the topsoil became very hard and crusted did they begin to lay without digging a basin. Here, they often matted down the vegetation and laid their eggs above the ground level. Of course, basins in duck blinds were constructed so that eggs were deposited right on wooden floors or, in some cases, on metal platforms or in dense cedar branches. In pine wood areas, large accumulations of needles made basin construction an easy task. This may be one of the reasons why pine habitat was much used for nesting sites.

Among many puddle ducks the only part of nest construction that preceded egg laying was the scraping of the nest bowl; no natural material was added to the basin, therefore, the first egg was always soiled (Sowls, 1955). Soiled eggs are a result of coming into contact with the moist nest basin that is unlined by vegetative materials. Soiled eggs were uncommon in black duck clutches early in the season. However, most nests were located in sites where large amounts of nesting material had accumulated such as honeysuckle tangles or near tree bases. As new plant growth began to give enough nesting cover, females began to construct nests at sites where nest material was less abundant. Then the first eggs in a clutch were often soiled. However, new plant growth did not occur in sufficient quality to disperse nesting until after females began renesting efforts. Hastily constructed basins with resultant soiled eggs were, therefore, judged in part to be a result of the hurried activities associated with renesting.

Females usually went to lay about one or two hours after sunrise. Some, however, were found to lay near mid-day. An increasing amount of time was spent at the nest site each day as laying progressed, apparently to pluck down for lining and to build up and make firm the sides of the basin.

NEST MATERIAL

Black ducks used the available material for construction of the nest basin. Since the majority of nests found were located in

loblolly pine growth, most were constructed of long pine needles.

The building of a nest almost wholly of pine needles in a mixed pine-hardwood forest was not always indicative of preference since pine needles were more resistant to decay and wind dissemination. Sometimes the ease of handling pine needles may have been a factor in selection of material from beyond the nest rim. Nests in poor cover-sites but with an abundance of nesting materials were selected on numerous occasions in preference to a nearby site with excellent cover and little basin material. This trait during the early part of the nesting season opened the way to wholesale predation by crows.

RE-USE OF NESTS

Black duck females occupied other females' nesting sites that had been successful, destroyed or deserted. For instance, in 1953 four of the basins found were used twice. In 1954, three of these same basins were used again; two being used twice during the 1954 season. Eight additional 1953 basins were re-used in 1954. In addition, of seven other basins which were constructed in 1954, five were used twice, one was used thrice, and one was used four times. Re-use of basins within duck blinds each season and from year to year was phenomenal—practically a swing-shift arrangement.

Recurrent utilization of basins was probably affected by two factors: (1) such sites were constructed in the best available cover and were therefore preferred and (2) re-nesting pressures later in the season caused females to hurry their nest building duties, therefore, they selected the furnished basins.

NESTING DENSITY

The average distance from one nest to the next nearest nest on Parsons Island in 1953 was 84 feet for 71 nests and on Bodkin Island it was 22 feet for 76 nests. Average distances between active nests was 188 feet and 39 feet on Parsons and Bodkin, respectively. Spacing seemed to be determined by the available cover and in some cases by the available basin material. Some hens were found on active land nests five feet apart.

Active clutches on blinds were often within 18 inches. In one of the latter cases one female gradually incorporated the other's clutch into her own and incubated both.

The distance between the locations of eight nests on which females were marked on Parsons and Bodkin Islands and the location of their renests ranged from 50 to 785 yards with an average of about 300 yards. On mainland areas, re-nesting distances would probably average much greater. Three first and second nests found on Parsons Island would be most indicative on mainland areas. There, the re-nesting distance averaged 540 yards.

Small islands within the study area and in nearby areas on the Eastern Shore of the Chesapeake Bay in Maryland showed phenomenal nesting densities of black ducks. For instance, Bodkin Island contained at least the following average number of nests per acre in 1953, 1954, 1956, 1957 and 1958: 15.2, 21.4, 10.0, 6.8, and 5.0, respectively. Long Marsh Island produced minima of 0.6, 2.0, and 0.9 nests per acre in 1956, 1957 and 1958. Little Island (about two acres) near Kent Island produced at least 2.5 and 2.0 nests per acre in 1957 and 1958, respectively. Swan Point Island in Kent County, Nelson Island in Talbot County, and one of the islands off South Point in Worcester County produced on a plane with Little Island in 1957. All were under five acres. Stewart and Robbins (1958) reported that 1,000 acres of brackish bay marsh in Dorchester County had a population of 53 breeding pairs in 1956. This number would produce a minimum of 0.053 nests per acre. However, if water areas were excluded and 50 percent of the birds re-nested a comparable figure to the present study would be about 0.2 nests per acre.

The presence of four nests on each of several offshore duck blinds indicated the nesting female's preference for small, isolated habitats. All of the above islands but Bodkin were marsh. In contrast to these small islands, Parsons Island (130 acres of varied habitat) produced minima of 0.5 and 0.4 nest per acre in 1953 and 1954, respectively. Similarly, Narrow and Norman Points (7⁷/₀ acres) on Kent Island produced at least 0.2 nest per acre in 1953. In all probability

these larger areas produced more nests per acre than were observed, since counting was, no doubt, less thorough.

A remarkable aspect of the high nesting densities found on these small islands and on offshore blinds was the apparent lack of discord between females that were often within sight of each other and a few feet apart. For example the average number of active nesting females on Bodkin Island on April 24 (an arbitrary date) in 1953 and 1954 was 5.8 and 2.8 per acre, respectively. Actually, these active densities should be about 9.7 and about 4.7 per acre respectively, since much of the marshy edge of the island was unfit and unused for nesting purposes. The distribution, as could be expected since cover is a prime factor, was very uneven (Fig. 2). Sites were most often chosen in dense vine tangles or brush piles which were unevenly distributed, but most often near the wooded edges. Thus, certain minute areas were suggestive of the breeding colonies found among other species of birds.

Egg Laying

The extent of production can be affected by many factors, such as past and present condition of breeding habitat and cover, individual differences of nesting females, predation and nest losses, size of breeding population, and, of great importance, climatic conditions. In this section the numbers of eggs will be analyzed in relation to environment and population.

CHRONOLOGY OF NESTING

The date of laying of the first egg for each year was determined by estimating from the number of eggs the date when the first egg had been laid in the earliest clutch found each year. The calculated dates for first laying were about March 17 in 1953, March 27 in 1954, March 20 in 1955, March 21 in 1956, March 9 in 1957, and March 20 in 1958. During the same years the latest clutch found had the first egg laid on June 18, July 4, June 26, June 13, June 14 and June 16, respectively. During these periods 161, 195, 54, 92, 140, and 89 black duck nests, respectively, were found. Since the 1955 data are limited they will not be used here.

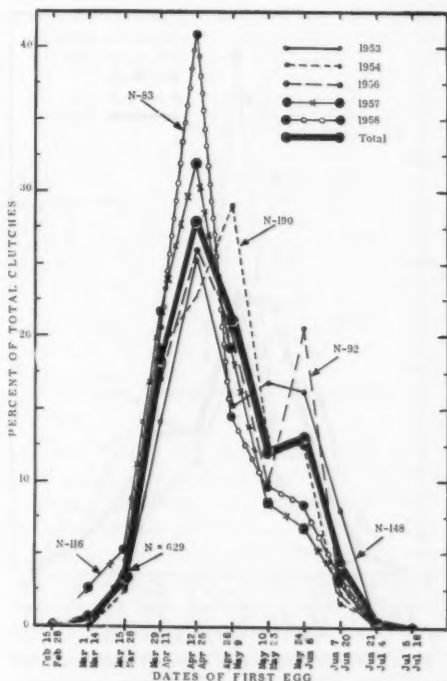


Fig. 7.—Dates of nesting in black ducks according to the date the first egg was laid in the clutch, Kent Island area, 1953-58.

The numbers of nests found must not be taken as an indicator of population size; the differences largely reflect the changes in annual purposes of study, especially in 1956-58 when care was taken not to excessively disrupt normal nesting routine and when much time which had been spent searching land areas in 1953-54 was spent searching duck blinds.

The nesting peaks occurred about April 30 in 1953 and between April 18 and 23 in all other years (Fig. 7). Early renesting due to abandonment of nests caused by renesting studies probably caused the earlier peak in all years but 1953. Secondary nesting peaks were notable in the years that nesting was excessively disrupted by the investigator. The first successful clutch under observation hatched on April 24 in 1953, April 28 in 1956, April 17 in 1957 and April 25 in 1958. The first young hatched about April 10 in 1954, as inferred from live-trapping and

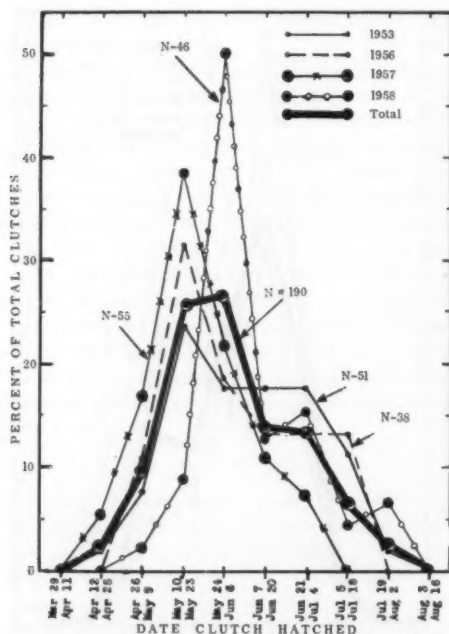


Fig. 8.—Hatching dates of black duck clutches in the Kent Island area, 1953–58.

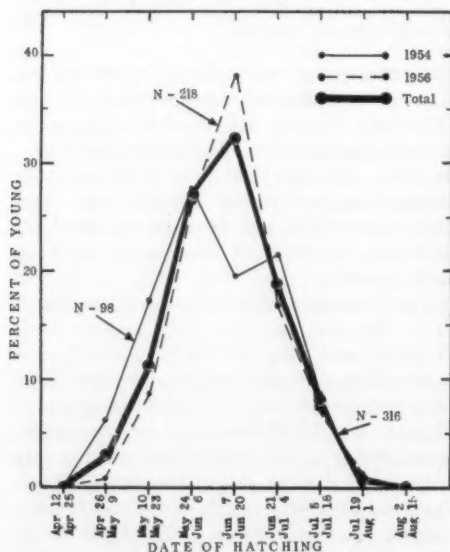


Fig. 9.—Hatching dates of black ducks estimated from ducklings caught in banding traps in the Kent Island area, 1954 and 1956.

sight observations. Peaks in hatching occurred during mid-May (Fig. 8) except in 1954 (about June 1) when renesting studies helped spread the season and in 1958 (about June 1), a cold, wet season.

The differences in dates of laying may be analyzed by comparison of the statistical significance of the date by which half of the nests had been started. The dates are: 1953, April 30; 1954, April 23; 1956, April 24; 1957, April 18; 1958, April 20. The date for 1953 is significantly different from that for 1957 and for 1958, but no other differences were significant.

Some information may be obtained about the survival of the early and the late broods by a comparison of the dates of hatching actually observed with the date of hatching calculated from juveniles. If the two dates agree, then one could conclude that no differential loss occurred early or late in the season. The only year available for comparison is 1956 (Fig. 9). The observed date by which half the clutches had hatched was May 29 while the calculated date (from aged juveniles) was June 7. However, the difference is not significant and thus no claim can be substantiated that the late broods survive better. However, since early broods are larger than later broods, a difference in the opposite direction is expected.

The dates of hatching were significantly different for 1956 (May 29) and for 1957 (May 16) although the dates of laying were not (April 24 and 18). It would appear that a greater loss of early clutches occurred in 1956 than in 1957. In the opposite direction is the contrast of 1953 and 1958. Although the dates of laying were significantly different (April 30 and April 20) the dates of hatching were not (June 2 and June 3) suggesting that the early clutches suffered great loss in 1958.

Broods observed during the seasons indicated that some young hatched about April 10, which indicated that the female began laying right after March 1. Broods seen late in August indicated that hatching occurred until about August 10. These data suggested that black ducks in Maryland can be found on active nests for an interval of about 160 days—a great contrast to the 60–90 day

interval near the northern limit of their breeding range.

CHARACTERISTICS OF CLUTCHES

The eggs of individual hens were usually identical to one another in shape, color, and size although one egg, sometimes the first and sometimes the last, was often smaller or larger. Bent (1923) accurately described black duck eggs as (1) elliptical ovate to nearly oval, (2) smooth shell with very little luster, (3) color varying from dull white or creamy white to various pale greenish buffy shades, and (4) measurements averaging 59.4 by 43.2 mm.

In conjunction with the findings of the present investigation and that by Sowls (1955) that the first egg was usually the most soiled in the clutch, black duck eggs could be chronologically dated by the amount of rough calcium or fecal deposits that adhered to the shell. Some eggs had a heavier accumulation of this deposit than others, but in almost all cases each egg was rubbed smooth by the third or fourth day after it was laid.

The amount of breast down in the nest was sometimes helpful to determine the stage of laying. A female normally began to line her basin with down when her clutch was about half complete. Down was then added very slowly until just before incubation began and then a profuse lining was laid down. Some hens, however, lined their nests very sparsely while others were lined profusely before 60 percent of the eggs were laid.

CLUTCH-SIZE

During the six nesting seasons, 360 complete clutches were found ranging in size from one to 14 eggs. One of three 14-egg clutches may have been a result of parasitism. A 1-egg clutch was found early in June and consisted of an egg of slightly larger than pigeon egg size with a thick, rugose shell.

Grouped by 2-week intervals with March 15 as an arbitrary starting point, clutch-size became significantly smaller as the season advanced (Table 4). There was no difference between years. The rate of change in clutch-size was noticeably greater during

TABLE 4.—Numerical production of eggs in clutches of black ducks in the Kent Island area as the season progressed, 1953-1958.

Two-week Period	Number of Clutches	Range of Eggs in Clutches	Average Number of Eggs	Decrease from Previous Period
March 15-28	17	10-14	10.9	—
March 29-Apr. 11	63	7-14	10.5	0.4
April 12-25	115	6-14	9.2	1.3
April 26-May 9	52	7-12	8.8	0.4
May 10-23	43	5-13	8.5	0.3
May 24-June 6	53	1-12	8.0	0.6
June 7-20	17	3-12	7.5	0.5
Total range or average	360	1-14	9.1 ¹	0.6

¹ Standard deviation of average clutch-size = 1.84.

the first half of the season and especially at the nesting peak (about April 20), and hence a regression was not calculated. Three reasons for this sudden decrease may apply: (1) the possible effect of increasing temperature (Kendeigh, 1941), (2) females that had earlier clutches destroyed were renesting, and (3) first year nesters, which are believed to lay smaller clutches than in later years, were just beginning to lay.

The age of some birds apparently affects their clutch-size somewhat. The mean size of primary clutches of marked females recaptured in successive years showed a slight increase (Table 5). The increasing age of females, however, appeared to affect inversely mean size of secondary clutches. However, the differences between mean clutch sizes of 1-2 year-old and 3-5 year-old females were not statistically significantly different.

Average bi-weekly clutch-size decreased by 3.4 eggs—from 10.9 to 7.5 eggs during the course of each nesting season (Table 4). Average clutch-size declined an average of 0.6 eggs per 2-week period. There was a similar bi-weekly decrease in the clutch-size of individual females during renesting and as the season progressed.

In two cases black ducks laid in another duck's nest. Eleven others may have been the result of similar parasitism (a total prevalence of 1.8 percent). For instance, at 12:30 p.m. on April 4, 1954, a clutch with one egg was found. At 1:50 p.m. on April 7,

TABLE 5.—Effect of age and renesting upon the clutch size of black ducks, 1953–1958.¹

Minimum Age Class of Nesting Female	Primary Clutches (March 15–May 9)			Second Clutches (May 10–June 20)			Total Clutches		
	Clutches	Range (eggs)	Average (eggs)	Clutches	Range (eggs)	Average (eggs)	Clutches	Range (eggs)	Average (eggs)
1 Year.....	37	7–11	9.2	34	6–12	8.6	71	6–12	8.9
2 Years.....	10	7–12	9.1	4	8–10	9.0	14	7–12	9.1
3 Years.....	8	8–11	9.8	6	7–10	8.7	14	7–11	9.3
4 Years.....	5	9–10	9.6	2	7–9	8.0	7	7–10	9.1
5 Years.....	4	9–11	9.8	0	—	—	4	9–11	9.8
1 year through min. of 2 years.....	47	7–12	9.2	38	6–12	8.7	85	6–12	9.0
3 years through min. of 5 years.....	17	8–11	9.7	8	7–10	8.5	25	7–11	9.3
Total.....	64	7–12	9.3	46	6–12	8.6	110	6–12	9.0

¹ Females caught for the first time on a nest were classed at a minimum age of one year (first-year nesters), although they may have been older. Since the bursa of Fabricius atrophies by the time females begin to lay eggs, the cloacal method of aging (Kortright, 1943) was no longer valid. Most birds, however, were banded when caught on the nest and had been aged at a previous date.

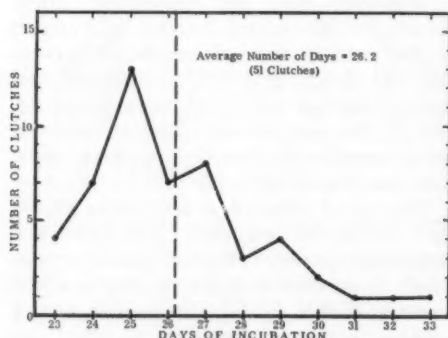


Fig. 10.—Incubation periods of 51 black duck clutches in the Kent Island area, 1953–58.

there were eight eggs—five tannish and three bluish-green. Another female had evidently laid in the nest on April 5, 6 and 7. In another case a black duck began laying in a mallard's nest after the mallard's fifth egg. The mallard deserted after her ninth egg. The black duck continued laying until the clutch numbered 20 eggs. Interspecific parasitism occurred twice when black duck nests were used by a ringnecked pheasant and a bobwhite quail.

Renesiting Clutches:—Two of eight marked females that renested laid equal primary and reneest clutches, two females laid one egg less in their renests, two females laid two eggs less, one female laid three eggs

less, and one female laid one egg more in her reneest. The average reduction in clutch-size between first nests (9.1 eggs) and renests (8.1 eggs) was 1.0 eggs. When the clutch-sizes for all years were divided into two parts at the point which was considered to begin entirely renesting clutches (early May) the average difference in clutch-size was found to be 1.5 eggs less in secondary clutches (8.1) than in primary clutches (9.6).

Incubation Period

The incubation period was computed as the time interval (to the nearest day) between the date of laying the last egg of a clutch and the day of hatching of the last egg. The period of incubation ranged from 23 to 33 days with a mode of 25 days (Fig. 10) and an average of 26.2 days. Trautman (1955) believes that the incubation range of black ducks would be 22 to 25 days under constant incubation conditions.

Artificial incubation of 13 clutches in a 99°F. incubator resulted in an average incubation time of 25.6 days, ranging from 22 to 30 days. Clutches incubated the longest by the female before they were taken to the incubator resulted in increased total incubation time: seven clutches taken fresh or in the first week of natural incubation averaged 23.7 days; two clutches taken during the second week of incubation hatched at an

average of 27.5 days; and four clutches taken during the third week of incubation averaged 28.0 days. Thus, constant incubating conditions resulted in several days less incubation time than occurred under natural conditions.

The length of incubation under natural conditions may be affected by multiple factors, among which may be the environmental temperature, precipitation, clutch size, nesting habitat, and, as noted, the amount of time which females attend their clutches.

To compare the effect of the variables of clutch size and season on the incubation time a multiple factor equation was calculated: $Y = 26.25 - 0.045X_1 + 0.11X_2$ where Y is incubation time, X_1 is days after April 6 (the earliest date of beginning incubation in the sample) and X_2 is clutch size. Since neither of the coefficients is significantly different from zero, no claim is made that date or clutch size affect the duration of incubation. Possibly data for clutches incubated in March would affect the results.

The type of nesting habitat may also affect the incubation period. Clutches in wooded habitat, which would not warm up very quickly during the spring months, had longer incubation periods than clutches located in duck blinds and marsh or cultivated areas. The former averaged 0.6 days and 2.1 days longer than the latter two habitats, respectively. However, only small samples were obtained for the latter habitats.

The number of times a female was interrupted during incubation was related to the duration of the incubation period (Table 6). Clutches from which females were flushed 8 to 17 times during incubation took an average of 1.5 days longer to hatch than did clutches from which females were disturbed 1 to 7 times, but the difference was not significant. All clutches vacated by females which were disturbed by the observer were covered with nesting materials immediately. Females were found to return to the nest in two to four hours after being disturbed. This time interval may be longer in the early stages of incubation and shorter during later stages. Temporary cooling may affect embryos more in the later stages of incubation

TABLE 6.—Number of interruptions of black duck females during incubation compared to the length of incubation period, 1953-1958.

Minimum Number of Times Females Flushed by Observer	Number of Clutches	Range of Incubation Period (Days)	Average Duration of Incubation (Days)
1-2	5	24-26	25.0
3-4	5	23-29	24.6
5-6	8	24-32	26.9
7-8	15	23-30	25.7
9-10	12	24-29	26.7
11-12	3	24-28	25.7
13-14	1	31-31	31.0
15-16	1	26-26	26.0
17-18	1	33-33	33.0
1-7	28	23-32	25.5
8-17	23	24-33	27.0
Total	51	23-33	26.2

as can be inferred from the data above on artificial incubation.

PROLONGED INCUBATION

Many females apparently incubated dead eggs far beyond normal incubation time. In only four cases was concrete evidence recorded. One female incubated obviously infertile eggs at least 58 days. One clutch whose embryos were killed by flood waters was destroyed by the observer after the female had incubated 34 days. Two other clutches killed by injections of dye into the eggs were incubated a minimum of 43 and 73 days.

These cases of prolonged incubation indicate the great loss that can happen to annual breeding success in areas subject to periodic, but very temporary, flooding. Females that persist in incubating dead eggs will not be available to attempt renesting. This problem could be very acute on tidal marshes.

THE PROCESS OF HATCHING

During the last few days of incubation nesting female black ducks were very reluctant to leave their nests and were difficult to flush. In many cases the hens would not go more than a few yards. This behavior occurred during the "pipping stage" when the young began their emergence from the eggs, and produced "pip" noises by hitting the egg shell with the egg-tooth.

Weak, sporadic, pipping sounds were

often heard in the eggs three to four days before the ducklings hatched. About 48 hours before the eggs hatched, pipping became very strong and regular. Ducklings also began their vocal "peep" at this time. Twenty-four to 30 hours before emergence, pip cracks were seen in the eggs. From 24 hours on, pipping became more rapid; the shell was chipped around its circumference about one-fourth the distance from the large end, the yolk sac was usually completely absorbed into the duckling, and the duckling emerged.

During the pipping stages of incubation, females normally showed the earliest signs of the "broken-wing" behavior when they were alarmed at the nest. One female exhibited this behavior in the fifth week of incubation, although all the embryos had died in the third week of development. Other females feigned injury as early as 16 to 18 days after incubation began. These latter cases occurred late in the nesting season and were probably females which had had several clutches destroyed.

All the eggs of a normal clutch hatched within three to four hours, and some ducklings were dry before the last emerged.

The egg-tooth used by ducklings to break their way from the eggs was usually lost between 24 and 36 hours after the young hatched.

Fate of Nesting

The small islands on the study area had very few predators. The common crow and fish crow nested and were very common on both Parsons and Bodkin Islands. One raccoon was known to be on Parsons Island during the nesting seasons of 1954 and 1956. A red fox was also present on Parsons Island for part of the 1956 nesting season. Pilot black snakes and black racers were present on Parsons Island, Kent Island, and the mainland. Muskrats were common but were never found to molest nests, although Kalmbach (1937) and Williams and Marshall (1937) report that they may be a factor of nest destruction in other regions.

During the six seasons, the fates of 731 black duck nesting attempts were compiled. In order to gain an idea of the outcome of

nesting under natural conditions all clutch mortalities caused by interference from the observer were omitted. Renesting studies in 1954 resulted in the collection of many clutches by the observer and the desertion of many nests by the female. In addition, abnormal activity in the vicinity of nests may have opened the way to added predation by crows. In 1955, when irregular visits were made to the study area, it was known that local persons collected numerous clutches of eggs from Bodkin Island.

NESTING SUCCESS

Actual nesting success under natural conditions is unknown since disturbances by the observer may have caused some females to abandon their clutches and may have pointed the way to predation in some clutches. Crows were, at times, noted watching the observer with great intent during searches for nests. The observer always ceased operations during these periods.

An illustration of the extent of predation when an observer caused disturbances among a dense nesting population can be taken from 1953. Very intensive nest searches were begun on Parsons Island in late March while on Bodkin Island searches were not begun until May 8. The observer, being unfamiliar with the birds, habitat, and predators, may have caused undue disturbances during the first month of observations. If the season is divided at May 2 and nesting success compared before and after this date, it was found that on Parsons success was 30 and 53 percent, respectively. On Bodkin success was 46 and 45 percent, respectively, during these periods. Percentages were compiled from 114 clutches. In 1956-58 the clutches begun before May were three, 74, and 16 percent, respectively, more successful (80, 87, 69 clutches) than clutches begun after May 2. Thus increasing predation during a season appears to be a combination of increasing crow vigilance toward nesting birds and toward observer disturbances.

Average nest success over the six years, excluding nest losses known to be caused by the observer, was 38 percent (Table 7). Success for individual seasons was 32 percent in 1953, 41 percent in 1956, 50 percent in

1957, and 63 percent in 1958. A decrease in interference by the observer may have resulted in the progressive increase in success. However, during the latter years greater numbers of observations were obtained in natural habitats where chances for success were better. Using only the last three seasons, 54.0 percent of the clutches were successful.

A comparison of success of primary and renest clutches showed that 56.5 percent of 230 clutches laid before May 2 were successful while 47.0 percent of 136 clutches laid after May 2 were successful.

UNDEVELOPED AND INFERTILE EGGS

Examination of 1091 black duck eggs from successful clutches showed that 3.8 percent did not reach hatching stage. In addition 1.8 percent of these eggs were left in nests, although they were within hours of hatching. To determine fertility, in 1956 a very thorough examination of 336 eggs disclosed that one (0.3 percent) was quite definitely infertile and that 7 (2.1 percent) had not developed beyond very early stages. Eggs that became pocketed in soft nests and were not turned regularly by the female may not have developed although fertile. Embryos in some of the eggs may have been killed by flooding.

The infertility observed here (0.3 percent) is comparable to the 0.7 percent found in the bluewinged teal by Bennett (1938). Kalmbach (1937), however, found only one infertile egg in about 250 nests of several waterfowl species.

DESERTION OF NESTS

Flooding of a nest almost always caused a female to desert if the clutch was incomplete. Marshes in the area were flooded by extra high tides at least six times from April 1 to May 10 in 1954 and at least seven times from March 22 to June 19 in 1956. Not only were nests destroyed by high water and abandoned by females during these tides, but the available cover, primarily salt-meadow cordgrass, was flattened, making it less attractive to nesting. Oftentimes females could elevate their nest basins as flood waters

TABLE 7.—Fates of nesting attempts of black ducks, Kent Island, 1953-1958.¹

Fate of Clutch	Number of Clutches	Percent of 574 Clutches
Successful clutches	218	38.0
Clutches abandoned because of:	66	11.5
tides	20	3.5
humans	4	0.7
mowing	3	0.5
unknown reasons	39	6.5
Clutches destroyed by:	287	50.0
crows	195	34.0
mammals ²	17	3.0
tides	2	0.3
humans	12	2.1
fallen tree ³	1	0.2
unknown agents	60	10.4
Infertile and addled (all eggs)	3	0.5
Total clutches	574	100.0
Abandonment due to observer	132	
Unknown fate ¹	25	

¹ Fates of most nests away from the Kent Island area were unknown since recurrent trips were not made to ascertain them.

² Three females killed on nests by raccoons. Another female found dead near her nest may have been killed by a raccoon.

³ Female killed.

rose, but in doing so their clutches were often exposed to marauding crows.

Although tidal flooding caused about 30 percent of the known cases of nest desertion, in the overall picture during this study (Table 7) the loss through flooding was minute (3.5 percent). However, only 16 percent of all nests found were in marshes; therefore, even on the small marshes found in the area losses through flooding would be over 20 percent.

Most disturbances at the nests of females in the very early stages of laying also caused them to desert. As the clutches were completed and, especially, in the later stages of incubation, desertion of a clutch by a female was rare. For instance, four incubating females returned to their hayfield sites when small islands of vegetation were left surrounding their nests. Two were destroyed later by crows, one female deserted after further human disturbances, and one hatched her clutch nine days after the field was mowed. During that nine-day interval the successful female was flushed on numer-

TABLE 8.—Destruction of complete clutches of black ducks by crows, mammals and unknown agents according to onset and stage of incubation, Kent Island area, 1953–1958.¹

Days of Incubation	0–7 Days	8–14 Days	15–21 Days	22–29 Days
Number of clutches destroyed	44	17	14	10
Percent of grand total	51.8	20.0	16.5	11.8

¹ Clutches taken by humans, destroyed by human activities, destroyed by tidal flooding, and destroyed by fallen tree, excluded.

ous occasions by raking and baling operations.

DESTRUCTION OF NESTS

One-half of all clutches were destroyed by various agents (Table 7). Of these, crows took about two-thirds, destroying about 70 percent while the eggs were being laid. Raccoons took about six percent of the destroyed clutches. Human theft or activity were directly responsible for 3.3 percent of all nest losses. Since these data were primarily for natural habitats, the destruction and theft of clutches by humans in nearby cultivated and residential areas may be several times greater.

Incomplete and complete clutches were equally susceptible to predation when considered percentage-wise. However, over 50 percent of predation on complete clutches occurred during the first week of incubation with continued decreases thereafter (Table 8).

During laying the female spent on the average only a few hours a day at her nest, but after she began to incubate she spent an increasing amount of time on or near her nest and was capable of defending her eggs against crows. In some cases, crows got only part of the clutch as evidenced by many cases of partial predation. In an extreme case for example, only five eggs of a 13-egg clutch hatched. The reduction was gradual from 13 to 12 to 10 to 5 eggs. In several other instances, eggs with peck-holes indicated that black duck females returning to their nests could drive off marauding crows. In 1953, 9.2 percent of the eggs in successful clutches were removed by crows and in

1956, 10.4 percent of the eggs were taken in this manner (an average of 9.6 percent).

Raccoons were destructive only during incubation periods. Apparently, raccoons usually struck at night when the female was present and sometimes could not escape. Three and possibly four females were killed on a minimum of 17 nests destroyed by raccoons (most located in duck blinds near to shore).

A 5-foot black racer was found in one nest in which the clutch had been incubated 18 days. Apparently the female would not defend, for she was absent.

RELATIONSHIP OF CROWS TO NESTING COVER

On the study area, the ranges of the fish crow and common crow overlap. The fish crow was believed to be the greater destroyer of clutches, because they not only spent less time in other activities, but they actually patrolled shorelines and duck nesting habitat more regularly. This observation agreed with Van Huizen's (1932) observations of the two species in the tidewater areas of the lower Eastern Shore of Maryland.

Crows did not begin to prey on duck nests until one to two weeks after the nesting season began, even though cover was usually very poor during this period. As more ducks nested crow predation rose sharply. Kalmbach (1937) believed that eggs were especially attractive to crows during their own nesting and that egg predation may be caused as much by nutritional demands and changing food preferences as by early season vulnerability of duck nests. It seems more probable that crows' food habits are directed by the availability of their prey. If they found that ducks' eggs could be obtained with little effort in certain areas, they began to frequent such areas.

As the duck nesting season progressed, nesting cover became more dense and crows then changed their food habits to more available prey. During the last half of May in the tidewater areas horseshoe crabs came into shallow water to molt and breed. These and dead fish were washed ashore in large numbers and provided food for crows.

Diamond-backed terrapins also began to lay their eggs along sandy beaches about this time. On July 7, 1953, 39 destroyed terrapin nests were recorded on a stretch of beach that measured 20 by 400 feet where it had been a common sight to see crows digging for several weeks preceding this date. The changeover from duck eggs to other foods occurred in early June.

Control of crow populations would not be economical except possibly during the first month of the nesting season. Van Huizen (1932) believed that reduction of the crow population by 50 percent would have little effect on nest predation due to the large feeding range of each crow. Both predators and their prey are associated with vegetative edges. If waterfowl could be influenced to disperse and nest over broad diversified areas the availability of their eggs to predators would decrease.

Discussion of Production

The black duck in the Chesapeake Bay region of Maryland presents no distinctive features in comparison with information about this species in other areas or even with other puddle ducks. The resident and migratory birds begin to pair in the fall; the male defends a small territory in the spring, but leaves within a week or two after the female begins incubating. The female renests if her first clutch is destroyed. The use of duck blinds for nesting is merely an extension of nesting in trees in the Chesapeake region and in New Brunswick (Wright, 1954). As is true in most birds, the size of the clutch declines during the breeding season, and yearlings lay fewer eggs than do adults.

A calculation of the production of ducklings in the region may be considered so that the population may be understood. In this process the deficiencies of data became conspicuous, and thereby serve to encourage collection of pertinent facts. The sequence of steps using the available data and assumptions follows.

1. Production depends upon the number of females in an area. This number is not known for this area, but we can use a group of 100.

2. The number of eggs laid depends upon

age (Table 5). However, the age composition of breeding females is not known, but must be somewhere near 50 percent yearlings because the mortality of adult females is about 50.2 percent (based on recoveries of 39 resident adult females). However, it is possible that a smaller proportion of yearlings than of adults nest. If the birds in Table 5 are a random sample of breeding birds then only half of the clutches belong to yearlings. Furthermore the clutch-size increases with age (Table 5) but the clutch-size for each age is not known. However, the number of 4- and 5-year old birds must be small. About the best that can be done is to use the average of 9.6 eggs per female for primary clutches (page 146).

3. Although success probably varies with season we can estimate that 56.5 percent (page 149) of these 100 females will successfully hatch a brood in their primary nesting attempt.

4. Since 15.2 percent of the eggs in the 565 successful nests will not hatch (pages 149 and 150) there will be $(56.5)(9.6)(0.848) = 460$ ducklings.

5. Now the 43.5 females who lost their entire clutches will attempt to renest. We do not know the proportion that renested but it is at least $8/51 = 0.16$ (page 138). It seems possible that the true proportion is double that figure and hence we might say that $(44)(0.32) = 14$ females renested.

6. Following through their sequence using a renest clutch success of 47.0 percent (page 149) we can calculate that seven successfully hatched a brood.

7. These broods came from clutches of 8.1 eggs (page 146) that suffered a loss of 15.2 percent. Thus $(7)(8.1)(0.848) = 48$ eggs hatched.

8. Obviously the 7 females that lost clutches would attempt to renest but the numbers are so small and the approximations so great that continuation of these calculations would be absurd.

Although there are many approximations and assumptions, these calculations suggest that around 510 ducklings are produced by 100 females. If 50 of these adult females die before the next breeding season then 50 of the 255 duckling females must survive to

replace the losses. The mortality of ducklings from hatching to flying stage (Class III stage) has been estimated to be a rather low 9.2 percent (Stotts, 1959) which indicates that 232 juvenile females will reach flight stage. If the mortality rate of females from flying age to breeding is more than 78 percent, then the population will decline. However, if some females are non-breeders this mortality figure would be too high.

Conclusions

The resident black duck, near the southern limits of its breeding range in the Chesapeake Bay, has some advantages over its northern relatives. Some benefits are: a frost-free period of 200 days in which to reproduce, relatively greater fertility of soils adjoining farmlands where it nests and feeds, a shorter harvest season, no rigors of migration, and relatively stable water levels that do not result in boom or bust conditions for nesting and other activities. One important disadvantage is the close proximity of the duck population to a much larger human population. This factor will in the future either provide for or condemn the existence of present high breeding populations of the black duck along the Eastern Shore of the Chesapeake Bay.

The best assurance of a sustained high production of resident black ducks is to intersperse nesting covers over broad areas. Since the earliest clutches average several eggs larger than later clutches and renests, adequate cover should be made available early in the season to increase success of primary nesting attempts. However, the value of renesting should not be overlooked when catastrophic events cause failure of early nesting.

Wooded areas along shorelines and at marsh edges probably produce the bulk of early nesting success since they are usually the least affected by adverse climatic factors. Intensive grazing of livestock should be minimized in these areas during winter periods to protect potential nest sites. Game managers might further enhance nesting by constructing small brush piles.

Managers providing for nesting on estuarine marshes should take into consideration

levels that will be consistently flooded by spring tides during the season. Burning such areas may be beneficial by dispersing nest sites to higher ground. Offshore duck blinds, which may serve as potential nesting sites, should be brushed with cedar, whenever possible, provided with a relatively flat roof, and constructed 100 yards or more from shore. See Stotts (1958B) for further management suggestions of duck blinds.

Small islands (and duck blinds) apparently provide an isolation factor that is conducive to high breeding populations. They should be preserved in natural condition whenever possible and managed to provide nesting cover when it is not available. Some islands might be economically constructed and strategically situated through use of dredged materials from channels and harbors.

Crows, the primary natural predator on black duck eggs, probably cannot be controlled by poisoning or similar management due to each individual's wide hunting range. Perhaps they could be temporarily side-tracked by intensive poisoning during the peak of black duck nesting. After black ducks have incubated about 15 days they become more attentive and their clutches are less available to crow predation. However, wide dispersal of black duck nests would be better protection against crow predation.

APPENDIX I—Common and scientific names of animals and plants mentioned¹

ANIMALS

Black duck	<i>Anas rubripes</i> (Brewster)
Black racer	<i>Coluber constrictor</i> (Linnaeus)
Bluewinged teal	<i>Anas discors</i> (Linnaeus)
Bobwhite quail	<i>Colinus virginianus</i> (Linnaeus)
Common crow	<i>Corvus brachyrhynchos</i> (Brehm)
Common grackle	<i>Quiscalus quiscula</i> (Linnaeus)
Diamond-backed terrapin	<i>Malaclemys terrapin</i> (Schœpf)
Fish crow	<i>Corvus ossifragus</i> (Wilson)
Gadwall	<i>Anas strepera</i> (Linnaeus)
Great blue heron	<i>Ardea herodias</i> (Linnaeus)

¹ Scientific names for plants are from Fernald (1950).

Horseshoe crab	<i>Limulus polyphemus</i> (Linnaeus)
Mallard	<i>Anas platyrhynchos</i> (Linnaeus)
Pilot black snake	<i>Elaphe obsoleta</i> (Say)
Raccoon	<i>Procyon lotor</i> (Linnaeus)
Ringnecked pheasant	<i>Phasianus colchicus</i> (Linnaeus)
Shoveler	<i>Spatula clypeata</i> (Linnaeus)
Wood duck	<i>Aix sponsa</i> (Linnaeus)

PLANTS

<i>Submerged Aquatics</i>	
Elfgrass	<i>Zostera marina</i> (Linnaeus)
Elodea	<i>Elodea canadensis</i> (Michaux)
Horned pondweed	<i>Zannichellia palustris</i> (Linnaeus)
Naiad (southern)	<i>Najas guadalupensis</i> (Sprengel)
Redhead grass (clasp- ing leaf pondweed)	<i>Potamogeton perfoliatus</i> (Linnaeus)
Sago pondweed	<i>Potamogeton pectinatus</i> (Linnaeus)
Sea lettuce	<i>Ulva lactuca</i> (Linnaeus)
Widgeongrass	<i>Ruppia maritima</i> (Linnaeus)
<i>Emergent Marsh</i>	
Groundsel bush	<i>Baccharis halmifolia</i> (Linnaeus)
Hightide bush	<i>Iva frutescens</i> (Linnaeus)
Needlerush	<i>Juncus roemerianus</i> (Scheele)
Panic grass (switch- grass)	<i>Panicum virgatum</i> (Linnaeus)
Saltgrass	<i>Distichlis spicata</i> (Linnaeus)
Saltmarsh cordgrass	<i>Spartina alterniflora</i> (Loiseleur-Deslongchamps)
Saltmeadow cordgrass	<i>Spartina patens</i> (Aiton)
Wax myrtle or bay- berry	<i>Myrica spp.</i>
<i>Upland</i>	
Blackberry	<i>Rubus sp.</i>
Black locust	<i>Robinia pseudo-acacia</i> (Linnaeus)
Greenbriar	<i>Smilax spp.</i>
Honeysuckle	<i>Lonicera japonica</i> (Thunberg)
Loblolly pine	<i>Pinus taeda</i> (Linnaeus)
Maple	<i>Acer spp.</i>
Oak	<i>Quercus spp.</i>
Poison ivy	<i>Rhus radicans</i> (Linnaeus)
Scrub pine	<i>Pinus virginiana</i> (Miller)
Sweet gum	<i>Liquidambar styraciflua</i> (Linnaeus)
Sour gum	<i>Nyssa sylvatica</i> (Marshall)
Trumpet vine	<i>Campsis radicans</i> (Linnaeus)

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Investigations of Inner Continental Shelf Waters off Lower Chesapeake Bay

Part I—General Introduction and Hydrography¹

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ABSTRACT

A series of monthly exploratory cruises into the neritic waters of the Atlantic Ocean adjacent to lower Chesapeake Bay were initiated late in 1959 to: (a) locate the eggs and larvae of fishes spawning in the area; and (b) to trace the transport of these stages by surface and subsurface currents into the Chesapeake Bay system. This paper will serve as an introduction to a proposed series describing the results of the cruises.

The survey area, which covers 50 nautical miles offshore and 60 miles in a north-south direction, is the neritic zone lying within the 20 fathom contour and extending from False Cape on the south to Wachapreague Inlet at the northern limit. Twenty-two offshore stations in addition to three stations in lower Chesapeake Bay were sampled monthly with surface and bottom plankton nets. Routine hydrographic data were taken at each station.

Surface and bottom water samples from the cruises of December through May indicated these preliminary points: From December through March the water column was essentially homogeneous with respect to temperature. Vernal warming began in April and thermal stratification progressed through May. The distribution of salinities was generally coastal in character with isohalines parallel to the coastline. The discharge of effluent from Chesapeake Bay produces frequent deviations from the normal coastal pattern. In general, the major component of the discharge from Chesapeake Bay passes out around Cape Henry and proceeds southward.

Drift bottle returns indicated that the survey area is crossed by a southerly drift having a velocity of 10 to 14 miles per day.

Introduction

Late in 1959 the Ichthyology Research Section of the Virginia Fisheries Laboratory initiated a series of monthly exploratory cruises into the neritic water of the Atlantic Ocean adjacent to Chesapeake Bay. The immediate goals of this study were to locate the eggs and larvae of fishes spawning in the area, and to trace the transport of these early stages by surface and subsurface currents into the Chesapeake Bay system. In the course of this investigation, it is anticipated that certain species which rarely enter Chesapeake Bay will be obtained. The distribution and transport of their eggs and larval stages may provide information on the basic problem of dispersal.

This is the first of a projected series of

papers dealing with spawning of estuarine and neritic fishes in the offshore waters adjacent to Chesapeake Bay. It is the intent of this paper to describe the objectives of the program, the area of study and the methods utilized. No biological results are included; rather, the biological data will form the basis of the remaining papers of the series. The hydrographic conditions encountered during the first six months of operation are described to provide a physical basis on which to interpret concentrations and dispersal mechanisms of eggs and larvae.

The importance of estuarine systems has drawn the attention of many biologists, oceanographers and geologists. Biologists have long recognized that estuaries are used as nursery grounds by neritic fishes and crustaceans. This role is especially pronounced in middle latitudes where many neritic species depend to a large degree upon

¹ Contribution from the Virginia Fisheries Laboratory, No. 95.

the resources of the estuary for growth and for maintenance of their populations. As regions of sharp transitions and gradients, estuaries support a fauna drawn principally from the sea, with but few components from freshwater environments. Most studies of this habitat have been principally concerned with an analysis of the biota *in situ* and have neglected the constant recruitment from neritic waters. Particularly lacking is knowledge of the mechanisms and pathways of dispersal from offshore waters into the estuarine systems.

The Chesapeake Bay system is a case in point. A number of organizations over a period of years have studied the biota within the Bay and contributing river systems. Yet the waters off Chesapeake Bay which contribute the bulk of that biota remain virtually unstudied, except for studies of a single species with attendant seasonal restrictions. It is well established that many of the commercially important fishes of the Chesapeake Bay area spawn in the offshore waters and in the typical pattern utilize the estuaries as nursery grounds. The distribution and abundance of juveniles within the estuarine system has been described by Massmann, et al. (1958, 1960), Haven (1957), and others. Although this work has been productive, there still exist significant gaps in the early life history of many important species. Precise sites and duration of spawning are unknown in most cases; for many species the eggs and earliest larval stages have yet to be described. Pathways and mechanisms of dispersal are subjects of speculation only. Furthermore, there are no extensive published studies covering all seasons that deal with the hydrography of these offshore waters. Numerous fruitful studies of this nature have been conducted in waters of the Gulf of Maine, Long Island Sound, George's Bank, and other regions; however, many of the species important in the Middle Atlantic region do not spawn in more northerly waters (Richards, 1959; Walford, 1938). For those species which are common to both areas, the season and duration of spawning may differ so widely that transference of information is not justified. These general inadequacies and limitations of previous

work in offshore waters pointed out the necessity for the present long-term study.

The authors are indebted to a number of individuals for aid in this project. Dr. William J. Hargis, Director of Virginia Fisheries Laboratory, has given special support and encouragement to this project since its inception. Mr. Dean Bumpus, Oceanographer of Woods Hole Oceanographic Institution, has provided drift bottles as well as assistance in hydrographic matters. Mr. Fred June, Chief of Menhaden Investigation, U. S. Bureau of Commercial Fisheries, provided a valuable piece of equipment in the Gulf-III High Speed Plankton Sampler. Colleagues too numerous to mention both in this and other laboratories have given assistance, encouragement and advice. To all of these we are grateful.

Methods

SELECTION AND DESCRIPTION OF THE SURVEY AREA

The selection of an offshore survey area was guided partially by previously published information related to known spawning sites and current patterns and in part by physical limitations. It was considered desirable that the area be as extensive as possible and yet one that could consistently be covered monthly. Within this limit of practicality, it was obvious that not all spawning areas which contribute to Chesapeake Bay could possibly be included. Thus an area was selected which must be traversed by any larvae in order to gain entrance to the Bay regardless of the site of spawning.

Current patterns on the continental shelf are poorly known for this area. The surface currents are known to consist of a general southerly drift, presumably a counter-current to the Gulf Stream (Miller 1952:10). Because of this southerly surface drift, it was judged that the survey area should extend as far north of the mouth of the Bay as possible. Subsurface currents, which may be extremely important in larval transport, are as yet unknown.

The area adopted is generally rectangular in shape. It covers 60 nautical miles in a north-south direction and extends approxi-

mately 50 miles offshore at the most distant point. Within this area of approximately 2500 square miles are 22 stations arranged in four transects of four stations and two transects of three stations. In addition, there are three stations in lower Chesapeake Bay spaced at ten-mile intervals from the Bay mouth to the mouth of the York River. The designation, location and depth of each station is given in Table 1. The numerical designation given each transect is derived from the latitude. All of the transects lie between 36° and 38° north latitude. The last two digits of the transect designation refer to minutes of latitude. Thus, the transect due east of the bay mouth is designated 700 and lies at 37° 00' N. The transect immediately north of this is designated 710 and lies at 37° 10' N. The four columns of stations are given Roman numeral designations I, II, III, and IV proceeding seaward. Thus all stations bearing the same Roman numeral are lined up in a north-south direction and all stations within any one transect are in line in an east-west direction.

In general, the survey area is the neritic zone lying within the 20 fathom contour and extending from False Cape on the south to Wachapreague Inlet at the northern limit.

SAMPLING TECHNIQUES

Goals and Limitations of Sampling:—

The field techniques were designed to sample surface and bottom waters in order to determine spawning sites and patterns of dispersal either into or away from Chesapeake Bay. Since the first efforts were largely exploratory in nature, we did not attempt to obtain measures of absolute abundance of either eggs or larvae. The sampling procedures, to be described below, are as consistent as possible so that measures of relative abundance are feasible. The fact that absolute densities are not sought does not preclude the use of statistical treatment, which will be applied whenever justified.

Description of Collecting Gear:—

Three general types of gear have been used for the collection of eggs and larvae: Clarke-Bumpus samplers, surface meter and half-meter nets, and the Gulf-III High Speed

TABLE 1.—Designation and location of stations over inner continental shelf waters off lower Chesapeake Bay.

Designation	Location		Depth in Feet
	N. Lat.	W. Long.	
CB-0	37 01	76 03	50
CB-10	37 08	76 11	40
CB-20	37 15	76 22	60
640 I	36 40	75 47	66
640 II	36 40	75 35	60
640 III	36 40	75 22	66
640 IV	36 40	75 10	120
650 I	36 50	75 47	56
650 II	36 50	75 35	48
650 III	36 50	75 22	72
650 IV	36 50	75 10	72
700 I	37 00	75 47	48
700 II	37 00	75 35	64
700 III	37 00	75 22	96
700 IV	37 00	75 10	114
710 I	37 10	75 47	20
710 II	37 10	75 35	54
710 III	37 10	75 22	84
710 IV	37 10	75 10	102
720 II	37 20	75 35	42
720 III	37 20	75 22	82
720 IV	37 20	75 10	82
730 II	37 30	75 35	36
730 III	37 30	75 22	82
730 IV	37 30	75 10	96

Plankton Sampler. This last piece of equipment is described in detail by Gehringer (1952:7-12). We attempted initially to use a uniform material for all cloth tow nets. A knitted nylon material produced by Marion Textiles has been widely and successfully used for ichthyoplankton sampling programs in inshore waters. This material, which has a mesh size of approximately 1 mm, was tried early in the sampling program. Nets prepared from this material were found to be unsatisfactory for offshore investigations because the large mesh size becomes even greater under the tension of towing. Whenever this material was used it is designated simply as "Marion Mesh." For all Clarke-Bumpus tows, the standard #2 (mesh size 0.25 mm) net was adopted.

All meter and half-meter surface nets used during the first six months were prepared from woven nylon material having a mesh size of approximately 0.8 mm. An adequate supply of dacron with a mesh size of 0.7 mm has been obtained and will be used consistently in the future.

Station Procedure:—Efforts at consistency of sampling have been only partially fulfilled. As mentioned above, certain gear used in the earlier cruises proved unsatisfactory. In addition, gear lost during rough seas could not always be replaced in time for the next cruise. In general, however, consistent station procedures have been followed as rigidly as availability of gear and weather conditions have permitted.

At each station, surface samples are obtained with two meter- or half-meter nets towed simultaneously from the stern. A Clarke-Bumpus sampler is towed at the surface off the starboard side. Bottom tows are made with a Clarke-Bumpus sampler attached to the same cable bearing the surface sampler. When weather conditions permit, the Gulf-III sampler is towed several feet above the bottom on a separate cable. On occasion, egg samples are obtained between stations by pumping surface water from the deck hose through a tow net.

Surface and bottom temperatures are taken at each station by means of a thermistor. Surface and bottom water samples are collected for salinity determination by titration. Surface and subsurface currents are of prime importance to this investigation. To this end we release six standard surface drift bottles at each station. In addition, six bottom drift bottles were released during several cruises on each of the Bay stations and on each station in the transect (No. 700) directly off the mouth of the Bay.

Hydrography

Hydrographic conditions in lower Chesapeake Bay are reasonably well-known, largely through the efforts of the Chesapeake Bay Institute of The Johns Hopkins University. For the offshore area adjacent to the mouth of the Bay, data are scattered and sparse. Although some data for this area are included in hydrographic surveys of

greater geographic extent, there is as yet no published account containing a detailed hydrographic description of the area covered by this paper.

It is not within the scope of the present work to provide this detailed treatment. However, three of the major hydrographic factors, temperature, salinity and current pattern, are of special interest to any study of spawning and dispersal of young stages. Temperature, salinity and bottom type will in part control the distribution of spawning activities. Temperature alone is probably the most important single factor acting to initiate spawning for most fishes, while current patterns are known to be a major factor in dispersal of eggs and larvae. These three factors will be treated in some detail. The results in this paper are based on data obtained from December, 1959 through May, 1960. All raw hydrographic data for each station and cruise will be included in a technical data report, to be issued by the Virginia Fisheries Laboratory.

TEMPERATURE

Published temperature data are more readily available than any other hydrographic factor. Bigelow (1933) and Parr (1933) summarized the available temperature records for continental shelf waters along the Atlantic coast. Both of these treatments relied heavily on lightship, light-house and cruise data. Since 1947, lightship data based on daily bathythermograph casts have been available. Daily temperature profiles are obtained from the Chesapeake Lightship (36°58'N-75°42'W) and are available for a ten-year period (Day, 1959B). Since this lightship is located within the area of study, these records provide a convenient standard of comparison with individual cruise data.

All surface temperatures cited are uncorrected for diurnal variation in air temperature. In obtaining a surface reading, the thermistor element is placed at least 18 inches below the surface so as to avoid the large diurnal fluctuation of the uppermost few inches. In constructing temperature patterns, 1°C intervals are used between isotherms. The small changes due to diurnal

fluctuations are not considered sufficient to change any of the general patterns.

Mean surface and bottom temperatures are summarized for each cruise in Table 2. Surface and bottom temperature patterns are shown in Figs. 1-12. In considering thermal patterns, it must be remembered that the data are not synoptic. Since a minimum time interval of three days exists between the first and last station of any one cruise, the construction of isotherms must depend on a liberal interpretation.

At the time of the first cruise (Dec. 7-10), the waters in the survey area had already achieved a state of vertical homogeneity with resulting instability. In fact, surface temperatures tended to be slightly below bottom temperatures, contributing further to thermal instability. At this season along the entire mid-Atlantic coast, isotherms tend to parallel the coastline with little latitudinal variation evident (Bigelow, 1933:99). Surface temperatures during the December cruise encompassed a range of 8.3° to 12.8°C. Temperatures increased offshore in a northwest to southeast direction. From Cape Henry northward the shoreline constitutes the upper half of the mid-Atlantic Bight and progresses in a general northeasterly direction. Thus, the surface pattern displays a gradient perpendicular to the shoreline.

Bottom temperatures extended from 9.0° to 12.8°C. The bottom pattern shows the 11° and 12° isotherms running approximately parallel to the coast. The seaward bottom gradient was less steep over most of the area than was the seaward surface gradient.

In January, surface cooling and wind mixing had resulted in a uniform water column of lowered temperature. The January cruise was interrupted by five days of strong northwest winds, which accounts for discrepancy in surface temperatures in the upper and lower halves of the survey area. The persistent northwest wind intensified the northwest to southeast gradient. The range in both surface and bottom waters extended from 4.1 to 9.9°C.

Temperature conditions in February did not differ greatly from those encountered in

TABLE 2.—Mean temperatures for December to May cruises over inner continental shelf waters off lower Chesapeake Bay.

Date of Cruise	Surface °C	Bottom °C
December 7-10, 1959	10.52	11.52
January 12-25, 1960	7.22	7.32
February 15-17, 1960	5.71	6.39
March 14-18, 1960	2.71	2.69
April 11-13, 1960	8.00	6.00
May 16-18, 1960	17.49	10.21

January. The low temperatures of January were not exceeded; the lowered surface mean was due to a decrease in high readings of the southeast corner. The absence of any persisting patterns of strong winds allowed the isotherms to parallel the coastline more closely. Over the period 1947-1956 the annual low in surface temperature was recorded during mid-February at the Chesapeake Lightship (Day, 1959B:83). This ten-year mean low corresponded closely to the mean surface temperature for the February cruise.

Along the mid-Atlantic coast vernal warming of surface waters can be expected to begin around the first of March (Bigelow, 1933:27). However, during March of 1960 surface cooling continued with a mean surface temperature of 2.7°C recorded. This approximates the annual low surface temperatures expected in coastal waters in the region from New York to Buzzards Bay. This mean is approximately 8°C below the Chesapeake Lightship mean for a comparable period over the last 10 years. In the northwest corner of the area, surface and bottom temperatures of less than 2°C prevailed. The isothermal pattern did not differ greatly from preceding months.

In early April vernal warming of surface waters began. The range in surface temperatures extended from 6.5 to 9.7°C. The past consistency in surface thermal pattern was now lost. The 8° isotherm divided the area into equal upper and lower halves. In each half, restricted cells of warmer or cooler waters existed. Minor stratification was evident with as much as 4°C separating surface and bottom temperatures on a few stations. Isothermal lines in bottom waters

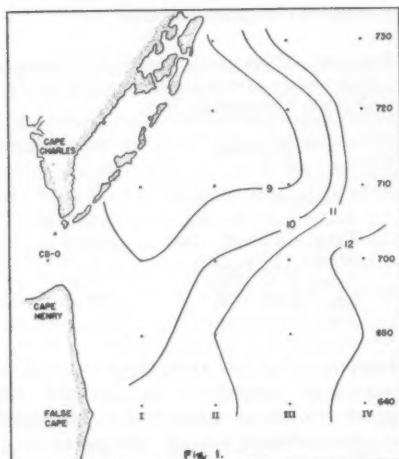


Fig. 1.

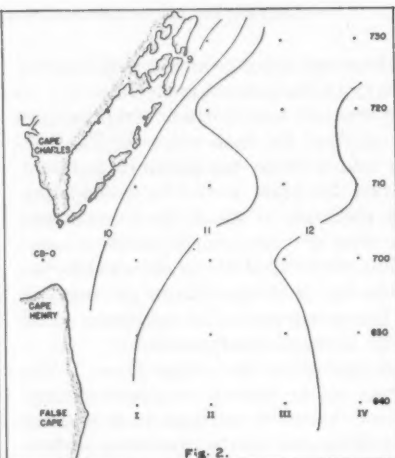


Fig. 2.

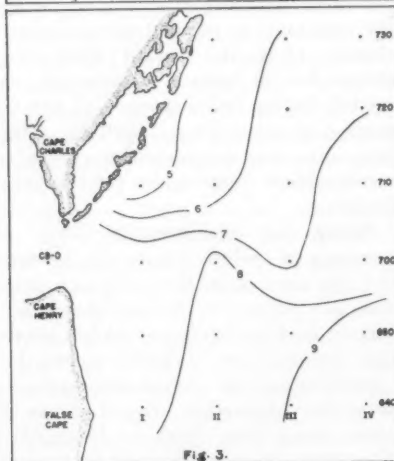


Fig. 3.

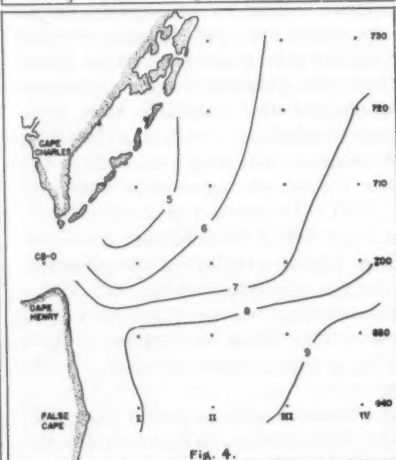


Fig. 4.

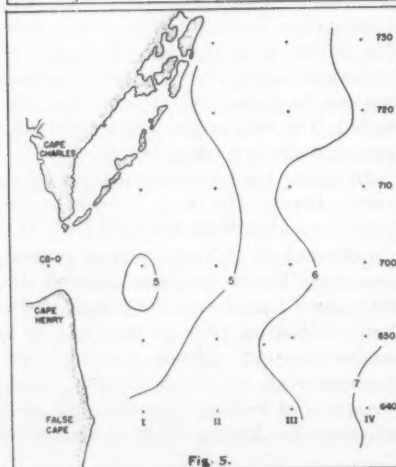


Fig. 5.

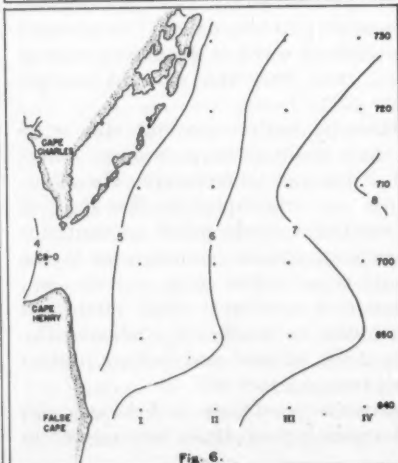


Fig. 6.

were parallel to the coastline but with a reversing gradient. The coolest waters occupied a band extending from the southwest to the northwest corner of the area. From this zone, temperatures increased both shoreward and seaward. This pattern obviously results from rapid warming of the shore zone to the west and the stable influence of warmer offshore waters to the east.

From mid-April to mid-May vernal warming and increased stratification progressed, leading to a higher degree of stability in the water column. At the deepest station (120 feet), a difference of 11.2°C existed; however, a mean difference of about 7° existed over the entire area. The May surface pattern repeated that encountered in April, with the 17° isotherm dividing the area into upper or lower halves. The reversing thermal gradient of April bottom waters was replaced in May by a steep gradient decreasing to seaward. A horizontal gradient exceeding 8°C was crossed over a distance of approximately 20 miles.

SALINITY

In general, the distribution of salinities over the continental shelf in the mid-Atlantic region is coastal in character with values from 32‰ or less close to shore increasing seaward (Bigelow and Sears, 1935:87). The chief factor tending to alter the basic pattern over the inner shelf is runoff of bays and rivers. Since our area encompassed one of the major points of dilution along the entire Atlantic coast, it is to be expected that deviations from the normal will be more frequent and of greater magnitude. Surface and bottom mean salinities for each cruise period are given in Table 3. Isohaline patterns are shown in Figs. 13–24.

During the period of the first cruise (Dec. 1959) salinities ranged from 23.4‰ between the Capes to 33.6‰ at the southeast corner of the area. The 32‰ isohaline approached

the shoreline just above and below the survey area. Directly east of the Bay mouth, dilute effluent forced the same isohaline some 35 miles offshore. The isohaline pattern suggests that some surface dilution spread to the northeast. Salinities near the bottom were considerably more uniform than on the surface and without great deviation from the typical coastal pattern.

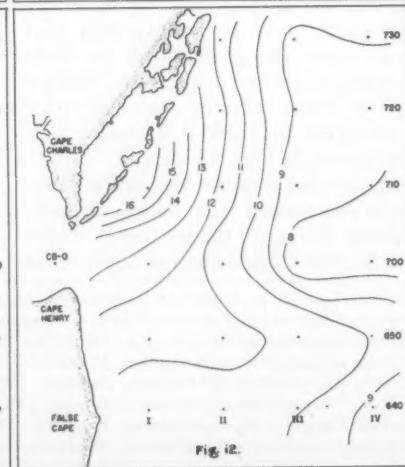
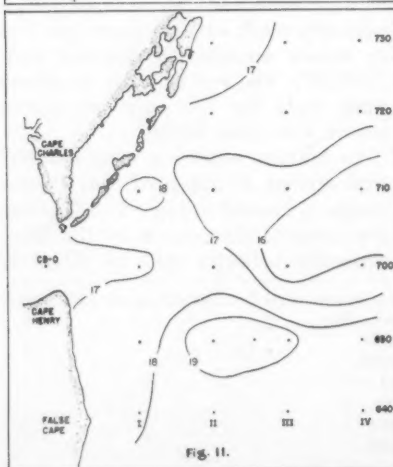
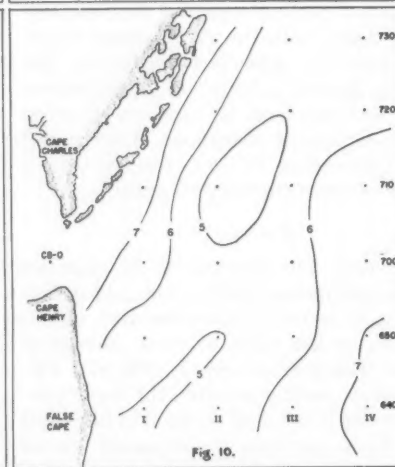
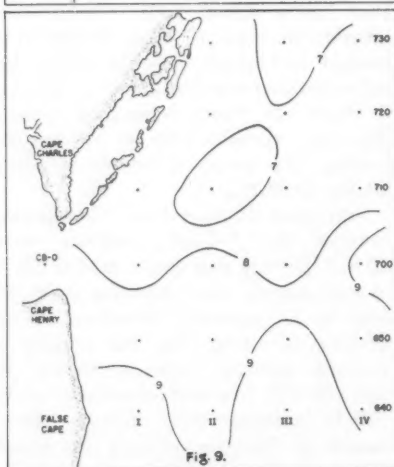
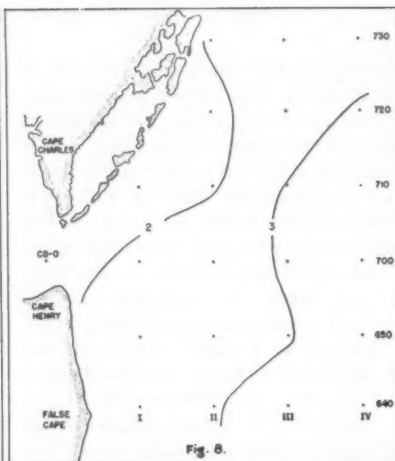
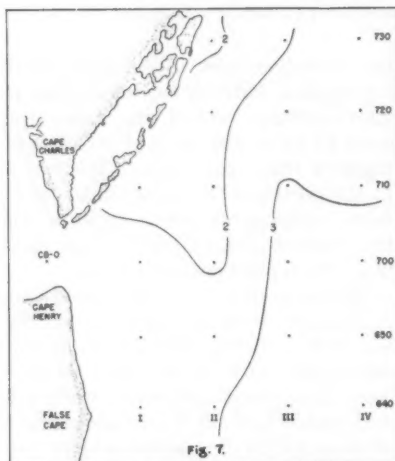
The range of surface salinities encountered in January over the offshore survey area was 28.0 to 33.5‰ . The pattern of isohalines shows that, with the exception of the innermost margin and southwest corner, salinities were rather uniform. In the southwest corner (Station 640 I) the lowered salinity indicated that dilute runoff from Chesapeake Bay passed out close to Cape Henry and proceeded southward close to shore. Bottom salinities also reached a low on Station 640 I. Since the water column is unstable at this time, there is little to prevent vertical mixing. The range of bottom salinities was 29.4‰ to 33.2‰ .

Increased dilution from Chesapeake Bay lowered the February surface mean to 29.8‰ . During this cruise period bay water of low salinity was spreading over the surface in an easterly direction. A salinity gradient of about 7‰ was crossed in the ten-mile interval between Station 700 II and 700 III. The surface salinity at Station 700 II (approximately 20 miles east of the mouth of Chesapeake Bay) was lowered to 24.9‰ . Salinities on the continental shelf normally reach a maximum in late February or March according to Bigelow and Sears (1935:87). The lowest value recorded in the same work for the open sea during this season was about 30.0‰ .

In bottom waters, a very different pattern existed. It appeared that a subsurface wedge of coastal waters ($> 30\text{‰}$) was moving towards the mouth of the Bay. It is generally believed that as dilute effluent

Figs. 1–6.—Surface and bottom temperature patterns recorded for December to February cruises over inner continental shelf waters off lower Chesapeake Bay.

1. Surface temperature distribution, December, 1959.
2. Bottom temperature distribution, December, 1959.
3. Surface temperature distribution, January, 1960.
4. Bottom temperature distribution, January, 1960.
5. Surface temperature distribution, February, 1960.
6. Bottom temperature distribution, February, 1960.



leaves the bay at the surface and spreads out over the coastal waters, replacement is accomplished by a wedge of coastal water which moves bayward near the bottom. In every month salinities tended to be lower on the surface at the inshore stations, but only in February did the isohaline pattern show clear evidence of the subsurface wedge.

Although the water column was quite uniform in temperature, lower surface salinities created a temporary condition of density stratification in the area containing stations 700 I, 700 II and 650 I. Calculations of σ_t showed a density gradient over 5g/kg between surface and bottom waters (σ_t and density *in situ* were practically equivalent at the depths in question, so densities *in situ* were not computed).

Decreased dilution during March allowed salinity patterns to approach the typical coastal pattern. The 31‰ isohaline divided the area into approximately equal east and west halves. Essentially the same conditions prevailed in bottom waters, so that the water column over the entire area was quite homogeneous.

The April mean surface salinity had dropped due to dilution in the southwest corner. Considerable effluent left the bay around Cape Henry and passed southward close to shore. Salinities less than 23‰ were encountered on two stations (650 I and 640 I) within this path. A line extending from Station 650 I (in a northwest direction) to the center of the survey area crossed a gradient of about 8‰. The effects of dilution were not nearly so obvious in bottom waters and no strong gradient existed except in the mouth of the Bay. As in March, temporary density stratification existed in the southwest corner. A density difference of 6.5g/kg occurred between surface and bottom waters.

May is generally the month in which the greatest dilution and the lowest surface

TABLE 3.—Mean salinities (‰) for December to May cruises over inner continental shelf waters off lower Chesapeake Bay.

Date of Cruise	Surface ‰	Bottom ‰
December 7-10, 1959	30.81	32.14
January 12-25, 1960	31.99	31.98
February 15-17, 1960	29.78	31.45
March 14-18, 1960	31.18	30.69
April 11-13, 1960	29.44	31.79
May 16-18, 1960	29.02	31.67

salinities exist along the shelf of the mid-Atlantic states (Bigelow and Sears, 1935:88). In the immediate offing of Chesapeake Bay, less regularity is exhibited in the period of low surface salinities; still, monthly low surface means tended to be concentrated in spring and early summer. In 1956 the low surface mean of 27.3‰ occurred during June (Bumpus, 1957:92). In 1957, three distinct lows appeared—March, April and June (Day, 1959A:86). In 1958, June was again the month of lowest mean surface salinity (Day, 1959B:83).

Surface salinities encountered on the May cruise were the lowest recorded during the six-month period covered in this report. The effects of runoff were very obvious in the isohaline pattern. It appears that the dilute effluent was split into two components. The smaller segment moved to the northeast, but the bulk of the effluent moved around Cape Henry and passed southward, close to shore. The salinity at station 650 I was reduced to 19.8‰. Across a diagonal of 14 miles from 650 I to 700 II a gradient of 11‰ was crossed.

The isohaline pattern of bottom waters clearly shows that little mixing of the surface effluent was occurring. A difference of at least 10‰ existed between surface and bottom waters on stations 640 I and 650 I. Thus, as in April, temperature and salinity were reinforcing factors in creating a stable

Figs. 7-12.—Surface and bottom temperature patterns recorded for March to May cruises over inner continental shelf waters off lower Chesapeake Bay.

7. Surface temperature distribution, March, 1960.
8. Bottom temperature distribution, March, 1960.
9. Surface temperature distribution, April, 1960.
10. Bottom temperature distribution, April, 1960.
11. Surface temperature distribution, May, 1960.
12. Bottom temperature distribution, May, 1960.

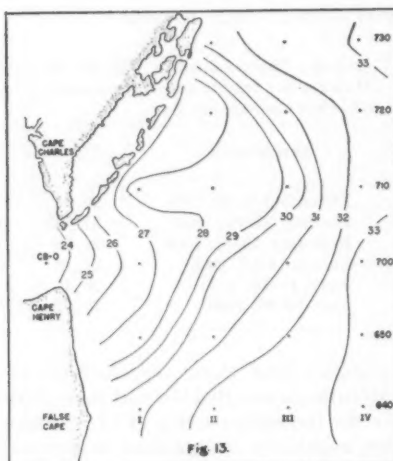


Fig. 13.

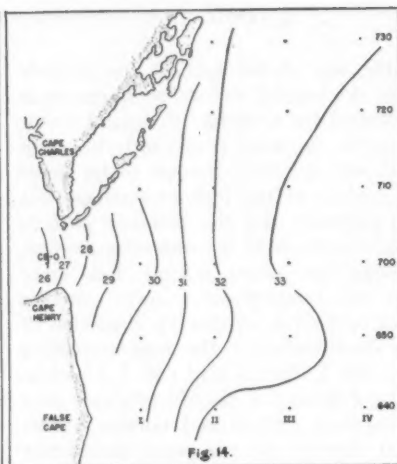


Fig. 14.

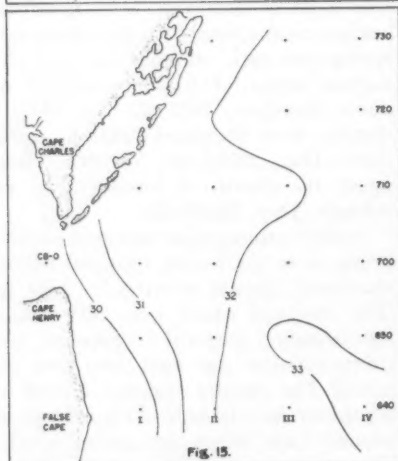


Fig. 15.

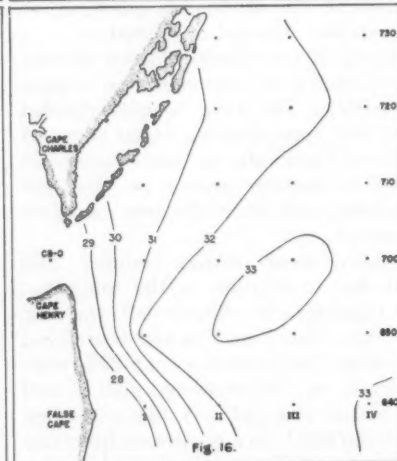


Fig. 16.

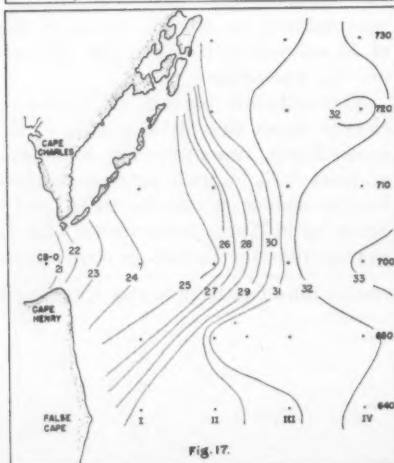


Fig. 17.

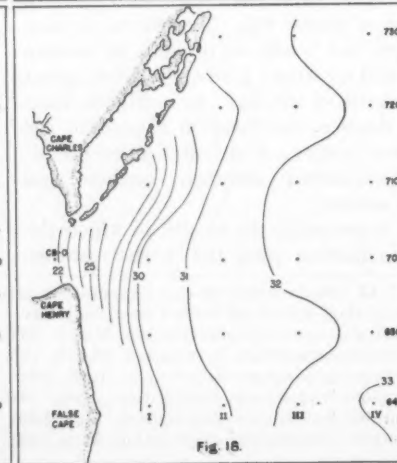


Fig. 18.

density gradient in the southwest corner. Over the remainder of the area bottom salinities exceeded surface values, but the differences were not extreme.

CURRENT PATTERNS

The coastal drift along the mid-Atlantic Bight is known to be southerly. Miller (1952:10) stated that this drift is not direct or confined in the sense of a broad slow current; rather, it meanders, divides, eddies and otherwise shifts. On the basis of drift bottle recoveries, Miller estimated that the velocity of the surface drift may be as much as 20 miles per day south of Chesapeake Bay.

The present investigation has been supplied with drift bottles by Mr. Dean Bumpus, Oceanographer of Woods Hole Oceanographic Institution. Recovery cards are returned to Woods Hole where the data resulting from recoveries will be treated in detail as part of a larger study. For this reason, the results which were obtained thus far will be described only in a general sense.

Six surface drift bottles were released on each offshore station and station CB-O for each of the six cruises. Of 828 surface bottles released, only 36 had been recovered and reported as of June 10, 1960. The low rate of recovery is due in part to the season in which the releases were made. During the mid-winter and early spring months the beaches on which strandings were likely to occur were largely deserted.

In general, the recoveries which were returned supported the findings of Miller (1952). Miller achieved a much bigger percentage of returns from releases made in the Chesapeake Bay area; however, all the releases in that investigation were made during the month of May when chances of recovery were much higher.

If we exclude two inshore stations—700 I

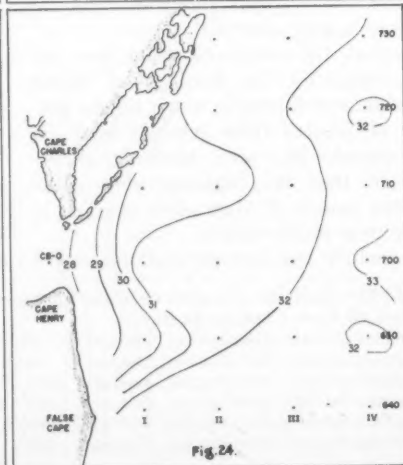
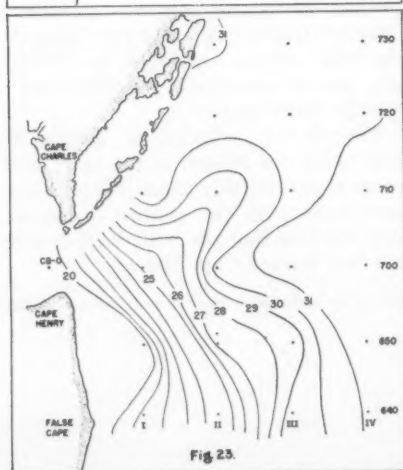
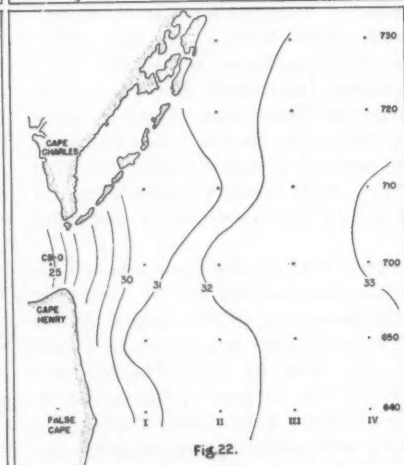
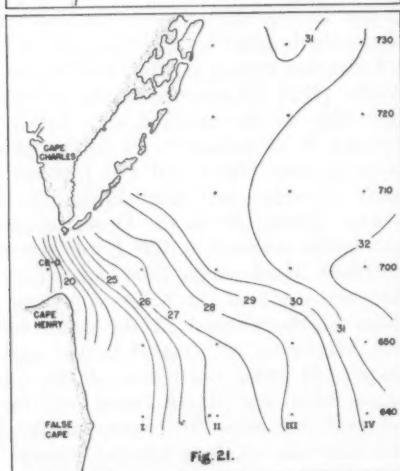
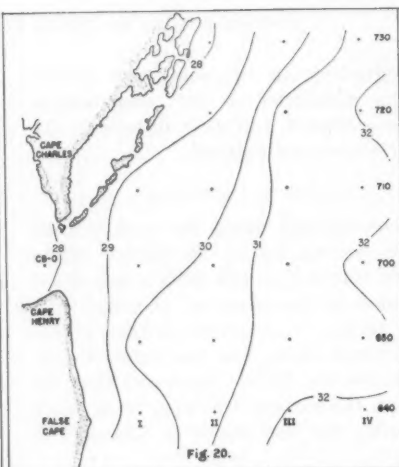
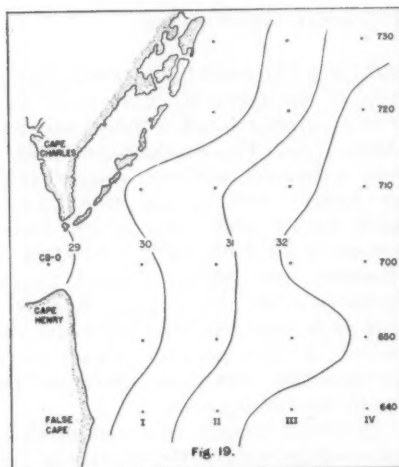
and 710 I, which will be discussed separately, most of the recoveries were made on the North Carolina beaches from Currituck to Oregon Inlet. This southwesterly drift is in close agreement with the results obtained by Miller. Most of the recoveries were made several weeks after release, thus are not useful for determining velocity of drift. However, two bottles covered minimum distances of 39 and 55 miles in three and four days respectively for minimum velocities of 13 miles per day. Those velocities are consistent with those determined previous to this investigation.

Of special interest to a consideration of spawning grounds in the vicinity of Chesapeake Bay is the possible existence of an anticyclonic eddy located just east of Cape Charles and slightly north of the Bay mouth. Miller (1952:12) postulated the presence of this eddy on the basis of May drift bottle returns. In the present investigation, returns from stations 700 I and 710 I affirm that such an eddy may exist during the mid-winter months. From the December cruise, one bottle released at 700 I was recovered at Little Machipongo Inlet, approximately 25 miles north of the point of release. Another bottle released at the same station was recovered at Cape Charles approximately 10 miles northwest of the release point. From the March cruise, two bottles released at station 710 I were recovered on the Bay side of Cape Charles, almost due west of the release station. Although these data are fragmentary, they do suggest that the eddy system described by Miller was not just a transitory condition but does exist at other seasons.

Five bottles released at station CB-0, just inside the mouth of the Bay, were recovered just outside Cape Henry. This is in agreement with the general isohaline pattern showing that the bulk of effluent leaves the Bay around Cape Henry.

Figs. 13-18.—Isohaline patterns recorded for December to February cruises over inner continental shelf waters off lower Chesapeake Bay.

13. Surface salinity distribution, December, 1959.
14. Bottom salinity distribution, December, 1959.
15. Surface salinity distribution, January, 1960.
16. Bottom salinity distribution, January, 1960.
17. Surface salinity distribution, February, 1960.
18. Bottom salinity distribution, February, 1960.



On the basis of previous work and results accrued during the first six months of this investigation, the surface current patterns in the survey area can be summarized as follows: The greater part of the survey area is crossed by a meandering but generally southerly drift having a velocity of 10 to 14 miles per day. Most of the effluent from the Bay passes out around Cape Henry and proceeds southward. Most of the coastal waters entering Chesapeake Bay pass around Cape Charles. An anticyclonic eddy, which may result from the three aforementioned currents, exists just east of Cape Charles.

The hypotheses of circulation patterns and seasonal hydrography, limited to six months data of what may be an atypical season, are provisional. For example, March 1960 was considered one of the coldest months on record at most points along the coast. Although the effects of unusual meteorological conditions have not yet been assessed, it is possible that they can produce considerable differences to coastal hydrography. For this reason the entire hydrographic picture will be re-evaluated in the light of the additional data at the end of the first complete annual cycle of operation.

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Figs. 19-24.—Isohaline patterns recorded for March to May cruises over inner continental shelf waters off lower Chesapeake Bay.

19. Surface salinity distribution, March, 1960.
20. Bottom salinity distribution, March, 1960.
21. Surface salinity distribution, April, 1960.
22. Bottom salinity distribution, April, 1960.
23. Surface salinity distribution, May, 1960.
24. Bottom salinity distribution, May, 1960.

Zoeal Stages of the Stone Crab, *Menippe mercenaria* Say

HUGH J. PORTER

ABSTRACT

Larvae of the stone crab, *Menippe mercenaria* Say, were reared from egg to a true crab stage in 27 days on a diet of *Artemia* nauplii. They were successfully cultured in swarms and placed in small compartments where their individual development was studied. Six zoeal stages were found and described, although only five are believed to occur normally in nature. One molt per zoeal stage was noted, and from 3 to 6 days were spent in each stage. Pre-zoeae were observed but these did not molt into a first stage. Such diagnostic characters as size and shape of antennae, and segment and seta numbers of endopodites, maxillules, maxillae and second maxillipeds, were constant in all zoeal stages. Telson appearance and chromatophore occurrence may also be helpful in identification. Comparisons were also made between known xanthid zoeae and *Menippe* zoeae. Experiments on salinity and temperature tolerance of the zoeae indicate that in a temperature range of 23 to 25°C, zoeae may not be able to survive in salinities of 27‰ or lower.

Introduction

This study begun in 1956, provides descriptions and illustrations of all the zoeal stages of the stone crab, *Menippe mercenaria* Say. This species is the largest member of the family Xanthidae in the Beaufort Inlet area of North Carolina. Its early development has never been described fully. Rathbun (1930:472-7) gave a general description of *M. mercenaria* and cited the geographic range as from North Carolina to Mexico. Hay and Shore (1918:439) stated that young crabs, after attaining a true crab form, are found under shell fragments in deep waters of harbor channels. After reaching a width of about one-half inch, the crabs live among oyster shells and rocks in shallower waters of harbors. At full size they make burrows 6 inches in diameter and 12 to 20 inches deep just below the low-tide mark of shoals. Binford (1912:18) reported that a female produced six egg masses within a period of 69 days, each mass containing between 500,000 and 1,000,000 viable eggs. The pre-zoea and first zoeal stages were first described by Hyman (1925), but a complete description of the larval development of *M. mercenaria* has not been recorded in the literature.

The author wishes to express his apprecia-

tion to Dr. M. R. Carriker, University of North Carolina, and Dr. John D. Costlow, Jr., Duke University for suggestions concerning the project, to Mr. Clarence E. Styron for aid in salinity and temperature studies, to Mrs. Hugh Porter for aid in preparation of the manuscript, and to Dr. A. F. Chestnut and the staff of the University of North Carolina, Institute of Fisheries Research for advice and criticisms concerning the project and manuscript.

Methods

Adult female *Menippe mercenaria* were held in indoor tanks supplied with running salt water. They were fed oysters, *Crassostrea virginica*, clams, *Mercenaria mercenaria*, and an occasional live fish. Females which developed a dark egg mass were placed in a large animal jar into which flowed sea water that had passed through a sand-and-shell filter. A siphon connected this container to another jar used as the larval collecting chamber. Another siphon extending to the bottom of the zoeal collecting jar was connected to a lower overflow chamber. This chamber prevented water in the collecting jar from overflowing and losing the more active zoeae which normally swam near the water surface.

Three-gallon, round, animal jars were found to be satisfactory for rearing large numbers of zoeae. Best results were obtained when the jars were blackened, except for the top 2 or 3 inches, and covered with an opaque lid. The positively phototropic zoeae constantly swam in the band of light near the top of the partially darkened jars and thus avoided entanglement in the refuse that accumulated on the jar bottoms.

When it was necessary to observe individual zoea, rearing was done in plastic boxes and Syracuse watch glasses conditioned in sea water.

Small groups of zoeae were separately fed *Chlamydomonas*, *Nannochloris*, a mixture of the sperm, embryos and larvae of *Mercenaria mercenaria*, Fleischmann's yeast and nauplii of *Artemia*, in order to determine food preferences. Zoeae that were fed *Chlamydomonas*, *Nannochloris*, and yeast did not survive, and those that were fed sperm, embryos and larvae of *Mercenaria mercenaria* demonstrated poor survival. Live, newly-hatched nauplii of *Artemia* were found to be the best food and were used throughout the experiment.

Refuse was removed from containers each day just before feeding. Zoeae were placed in clean containers and in freshly filtered sea water every second day. The uncontrolled culture-room temperatures were usually about 28°C but ranged as high as 33°C. Salinities ranged between 32 and 35‰.

Experiments were conducted with zoeae reared in the following salinities: 23, 27, and 33‰, to examine the possible influence of salinity and temperature on larval development. Some were reared in compartmented plastic boxes, six zoeae per compartment (Costlow and Bookhout, 1959). These were placed in a water table where water temperatures, dependent on room and incoming sea water temperatures, ranged between 27 and 29°C. Other zoeae were reared in an air-conditioned room where temperatures varied between 23 and 25°C. They were placed in Syracuse watch glasses, 10 zoeae per glass (Costlow and Bookhout, 1959). The zoeae placed in 23‰ were previously acclimatized for 15 minutes in a salinity of 27‰.

Drawings were made from preserved specimens. The mounting medium, Polyvinyl Lactophenol (Thompson, 1958) and the stain Chlorazol Black E. (Cannon, 1937) were helpful. Appendages were dissected from zoeae with fine insect pins. A Whipple disk used with both a compound and dissecting microscope aided in drawing figures to scale.

Results

Menippe mercenaria spawned as many as four egg masses in indoor sea-water tanks during summer months with no intervening molts or matings. About two weeks were required for eggs to hatch. Following hatching of a sponge, it was not unusual to find the same female carrying an egg mass one week later. A female whose spawning history before capture was unknown was observed to molt and mate immediately after spawning once in the laboratory.

A female that spawned at least four egg masses in one summer ate 40 clams ranging in length from 40 to 102 mm during a 32 day period. Temperatures during this time ranged between 27 and 31°C.

Large mortalities among zoeae occurred during all experiments. In mass culture, a few individuals were raised to the megalops stage in 19 days and to an early juvenile stage in 27 days. Three to 6 days were required for zoeae to go from one stage to another. Results of salinity and temperature studies indicate that mortalities increase with lower salinities and temperatures (Table 1 and 2). In experiments where development of individual zoeae was followed, only one molt per stage was noted.

LARVAL STAGES

Pre-zoea:—This stage (Hyman, 1925) was seen but not observed to molt into a first-stage zoea.

First zoea:—(Fig. 1) Cephalothorax with slight interorbital bulge; dorsal and rostral spines approximately equal in length, slightly more than twice length of lateral spines (Fig. 1, A and C); dorsal not so straight as rostral spine, directed posteriorly; lateral spines pointed slightly downward; eyes large, non-stalked, outwardly composed of six-sided facets.

Antennule conical (Fig. 1, E); with six bladelike distal sensory flagella, five about as long as protopodite, one shorter and narrower than others.

TABLE 1.—Percent zoeae of the stone crab, *Menippe mercenaria*, of July 24–August 20, 1959 experiment reaching a recognized zoeal stage in a known temperature-salinity environment.

SERIES 27–30°C.

Salinity ‰	Zoeal Stage					Original Number of Zoeae
	2nd	3rd	4th	5th	6th	
33	17	14	8	6	—	36
27	7	5	4	4	—	54
23	13	—	—	—	—	60

SERIES 23–25°C.

Salinity ‰	Zoeal Stage					Original Number of Zoeae
	2nd	3rd	4th	5th	6th	
33	5	3	1	1	—	100
27	1	1	—	—	—	100
23	1	—	—	—	—	100

TABLE 2.—Percent zoeae of the stone crab, *Menippe mercenaria*, of August 10–September 6, 1959 experiment reaching a recognized zoeal stage in a known temperature-salinity environment.

SERIES 27–30°C.

Salinity ‰	Zoeal Stage					Original Number of Zoeae
	2nd	3rd	4th	5th	6th	
33	31	17	15	13	4	48
27	27	13	8	5	2	60
23	25	12	8	3	—	60

Antenna (Fig. 1, G) about one-half length of rostral spine; protopodite tapered to point, with two rows of setules from mid-length to near tip; exopodite with long heavy spine near distal end extending slightly beyond protopodite, spine five to six-tenths length of exopodite.

Mandible (Fig. 1, I) small and simple; teeth on lateral and posterior cutting edges indistinct.

Maxillule (Fig. 1, K) flat; endopodite two-segmented, with one long seta on lateral surface of first segment and four long setae on distal end of second segment; protopodite bilobed, basal endite with five stout, hairy setae, coxal endite with six stout, hairy setae, some setae on basal endite heavier than those of coxal endite.

Maxilla (Fig. 1, M) platelike; endopodite bilobed with three setae on each lobe; scaphognathite of protopodite with four plumose setae on outer margin, distal portion produced into thin, hairy process; basal and coxal endites bilobed, first and second lobes of each with 4 and 5 setae,

respectively; posterior margin of second coxal endite slightly pubescent.

First Maxilliped (Fig. 1, O) exopodite partially bisegmented, with four natatory hairs at distal end; basipodite with 10 setae on inner margin; endopodite with five segments, setae count on segments progressing proximad: 5-2-1-2-2.

Second Maxilliped (Fig. 1, Q) exopodite similar to first maxilliped; with four setae on inner margin of basipodite; three-segmented endopodite with setae count progressing proximad: 4-1-0.

Abdomen (Fig. 1, A and S) cylindrically shaped, with five segments and telson; each segment with two small setae on posterior dorsal surface; second segment (Fig. 1, S) with pair of mid-ventral, anteriorly pointing spines; third segment (Fig. 1, S) with pair of mid-ventral, posteriorly pointing spines; fourth and fifth segments (Fig. 1, A and C) each with a pair of posteriorly pointing spines on posterior dorsolateral surface; telson a furca, rami approximately two-thirds length of telson, three long tapering spines along inner surface of rami, each ramus with row of setules on inner and outer margins (Fig. 2, S and T), setae replacing setules on mid-portions of innermost spines (Fig. 2, S); mid-lateral and mid-dorsal surface of each ramus with a very small spine (Fig. 2, S and T).

Chromatophores were found in the following locations: interorbital, supracardiac, anterior surface of dorsal carapace spine, postero-ventral lobe, labrum, mandible, sternum, base of antennule, base of antenna, basipodite of first and second maxillipeds, dorsolaterally on first abdominal segment, ventrolaterally on second through fifth abdominal segments and on telson. In preserved specimens coloration of chromatophores fades in the dorsal carapace spine.

Second zoea:—(Fig. 1) Eyes stalked (Fig. 1, B); posterior margin of cephalothorax with several setae (Fig. 1, D). Antennule (Fig. 1, F) and antennae (Fig. 1, H) unchanged; antennule sometimes with only 4 large and 1 small sensory flagella. Posterior cutting teeth of mandible (Fig. 1, J) more differentiated than in first stage; posterior border of right mandible with one more tooth than left mandible. Basal and coxal endites of maxillule (Fig. 1, L) with seven setae each; protopodite with one seta on dorsal margin. Scaphognathite of maxilla (Fig. 1, N) with 11 or 12 plumose setae, no distal hairy process; basal and coxal endites with no change. Exopodites of first and second maxillipeds (Fig. 1, P and R) with six natatory hairs at distal end; no other change noticeable. Middorsal surface of first abdominal segment (Fig. 1, D) with one small seta; third, fourth and fifth segments each with pair of spines on posteroventral surface, spines decreasing progressively in size (Fig. 1, B); median surface of telson with an occasional pair of small setae, setae less than one-fourth size of spines on inner margin of rami; rami proportionately not so long as in first stage.

Third zoea:—(Fig. 2) Posterolateral border of cephalothorax with five setae (Fig. 2, C). Muconate antennule (Fig. 2, E) with three of sensory

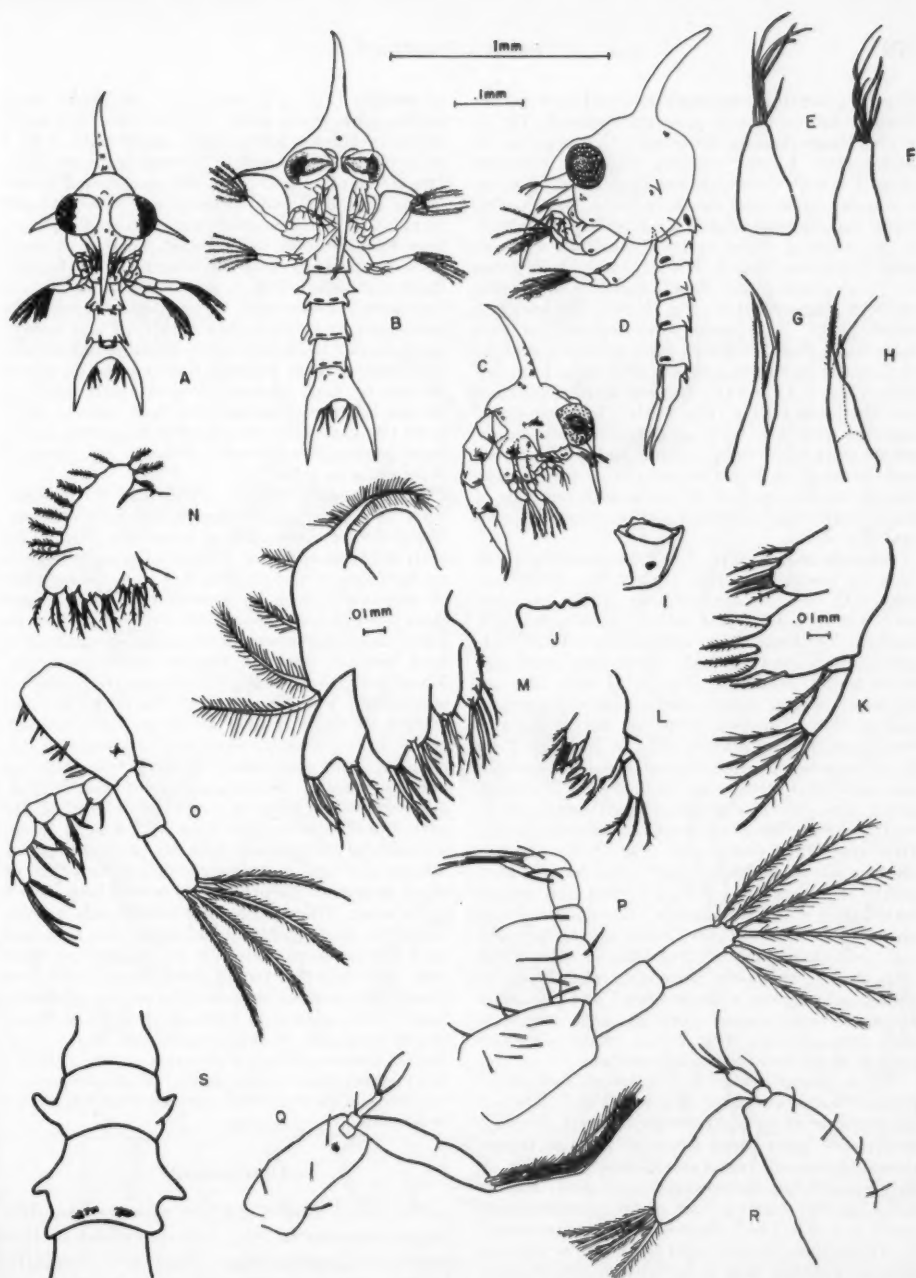


Fig. 1.—First and second zoeal stages of *Menippe mercenaria*. A, ventral view of first stage; B, ventral view of second stage; C, lateral view of first stage; D, lateral view of second stage; E, antennule of first stage; F, antennule of second stage; G, antenna of first stage; H, antenna of second stage; I, mandible of first stage; J, posterior cutting edge of second-stage mandible; K, maxillule of first stage; L, maxillule of second stage; M, maxilla of first stage; N, maxilla of second stage; O, first maxilliped of first stage; P, first maxilliped of second stage; Q, second maxilliped of first stage; R, second maxilliped of second stage; S, dorsal view of second and third segments of first-stage abdomen. Scale of whole zoea indicated by the 1 mm line. Scale of zoeal parts, unless otherwise indicated, shown by 0.1 mm line.

flagella quite thin, one flagellum short and another slightly subterminal in position. Antenna (Fig. 2, G) unchanged except for hump which is anlage of endopodite. Lateral cutting edge of mandible (Fig. 2, I) with three medium-sized, rounded teeth, a number of smaller teeth between larger ones; inner cutting edge (Fig. 2, J) developed for grinding or crushing. Basal endite of maxillule with one additional seta (Fig. 2, K), total number of setae on basal endite eight. Scaphognathite of maxilla with 18 plumose setae (Fig. 2, M); no change in other parts. First endopodite segment of first maxilliped (Fig. 2, O) with three setae; exopodites of first and second maxillipeds with eight natatory hairs (Fig. 2, O and Q). Buds of third maxilliped and chelipeds visible (Fig. 2, C). First abdominal segment with three setae on dorsal surface; an unarmed sixth abdominal segment added (Fig. 2, S); rami making up 75 to 80 percent of total telson length; median surface of telson with one pair of setae, beginnings of second pair occasionally present (Fig. 2, S).

Fourth zoea:—(Fig. 2) Cephalothorax with 12 setae on posterior margin (Fig. 2, D). Antennule base with one side swollen (Fig. 2, F); two new thin flagella added just below those previously present. Terminal tip of endopodite bud at midpoint of antenna (Fig. 2, H). No noticeable change in mandible. Maxillule (Fig. 2, L) with 12 setae on basal endite; coxal endite with eight setae; protopodite with two setae on dorsal margin. Scaphognathite of maxilla (Fig. 2, N) with 27 or 28 plumose setae; each lobe of basal endite with one additional seta, setae count for both lobes, 5 and 6; first lobe of coxal endite with setae count continuing at four, setae count of second lobe six. First maxilliped endopodite (Fig. 2, P) with six setae on distal segment, setae count for all endopodite segments now: 6-2-1-2-3; first and second maxillipeds with 10 natatory hairs on distal end of exopodite. Buds of third maxillipeds, chelipeds and pereopods more evident than in third stage (Fig. 2, D); chelipeds noticeably chelate. First abdominal segment with between 5 and 7 setae on dorsal surface; second through sixth segments with pleopod buds (Fig. 2, U); telson with two pairs of small setae on median surface.

Fifth zoea:—(Fig. 3) Posterior margin of cephalothorax with 20 to 22 setae (Fig. 3, B); dorsal and rostral spines through unequal development more than three times as long as lateral spines. Antennule with endopodite bud (Fig. 3, C); sensory flagella arranged into tiers, flagella count per tier starting from distal antennule end: 4 to 5, 1, 6 to 8, 2 to 7; flagella on lower tiers smaller, thinner and divided into two equal or unequal groups. Antenna (Fig. 3, E) with length of endopodite nearly that of exopodite; spine on exopodite about three-fourths length of exopodite. Mandible (Fig. 3, G) with palp bud on anterior surface. Maxillule (Fig. 3, H) with 14 to 17 setae on basal endite; 11 to 12 setae on coxal endite; both endites with an occasional seta on anterior margin and three setae on posterior margin. Scaphognathite

of maxilla (Fig. 3, J) with 36 to 39 setae; basal endite with seven setae on first lobe and eight setae on second lobe; coxal endite with 4 or 5 setae on first lobe and 6 to 10 setae on second lobe. Distal end of exopodites of first and second maxillipeds (Fig. 3, L and M) respectively with 11 and 12 natatory hairs, an additional but smaller natatory hair on outer subterminal position of each; both maxillipeds with no change in endopods; third maxilliped (Fig. 3, N) with protopodite, an unsegmented epipodite, exopodite and a partially five-segmented endopodite. Cheliped and pereopods similar in development to third maxilliped. Abdomen (Fig. 3, P) with 8 or 9 setae on dorsal surface of first segment; 3 to 5 small setae on median surface of telson; first four pairs of pleopods elongate with protopodite, exopodite and a small endopodite on each; fifth pair of pleopods continuing as a bud.

Sixth zoea:—(Fig. 3) Fifth and sixth zoeae with no apparent differences in cephalothorax. Distal end of endopodite of antennule (Fig. 3, D) with an occasional seta; number of sensory flagella on each tier; 4 to 5, 1, 6 to 8, 4 to 6. Endopodite of antenna (Fig. 3, F) sometimes a little longer than protopodite; endopodite with long setae on distal end, sometimes extending end of endopodite to a location opposite that of exopodite spine. Mandible with no noticeable change. Basal endite of maxillule with 23 to 29 setae (Fig. 3, I), anterior margin occasionally with two setae, posterior margin with 3 to 5 setae; coxal endite remaining unchanged (one zoea observed with two setae on anterior margin). Scaphognathite of maxilla (Fig. 3, K) with 39 to 44 setae; first lobe of basal endite with 8 or 9 setae, second lobe with 9 to 11 setae, second lobe occasionally with one seta on anterior margin and two on posterior margin; first lobe of coxal endite with 4 or 5 setae, second lobe with 8 to 11 setae. First and second maxillipeds usually similar to those in fifth zoeal stage (one zoea had only six natatory hairs on its exopodites—this same zoea had 13 setae on the protopodite of first maxilliped and one seta on that of second maxilliped); (one zoea seen with eight hairs on distal end of exopodite of third maxilliped (Fig. 3, O)). Dorsal surface of first abdominal segment with 9 to 11 setae; setae on exopodites of all pleopods or on only last pair; median surface of telson with 4 or 5 setae.

Discussion

Six zoeal stages for the stone crab, *Menippe mercenaria* Say, are described in this paper. Chamberlain (1957), Connolly (1925), Hart (1935), Hyman (1925) and Lebour (1922) described four zoeal stages for the larval development of various xanthids.

Pre-zoeae for *M. mercenaria* were described and reported to molt within minutes

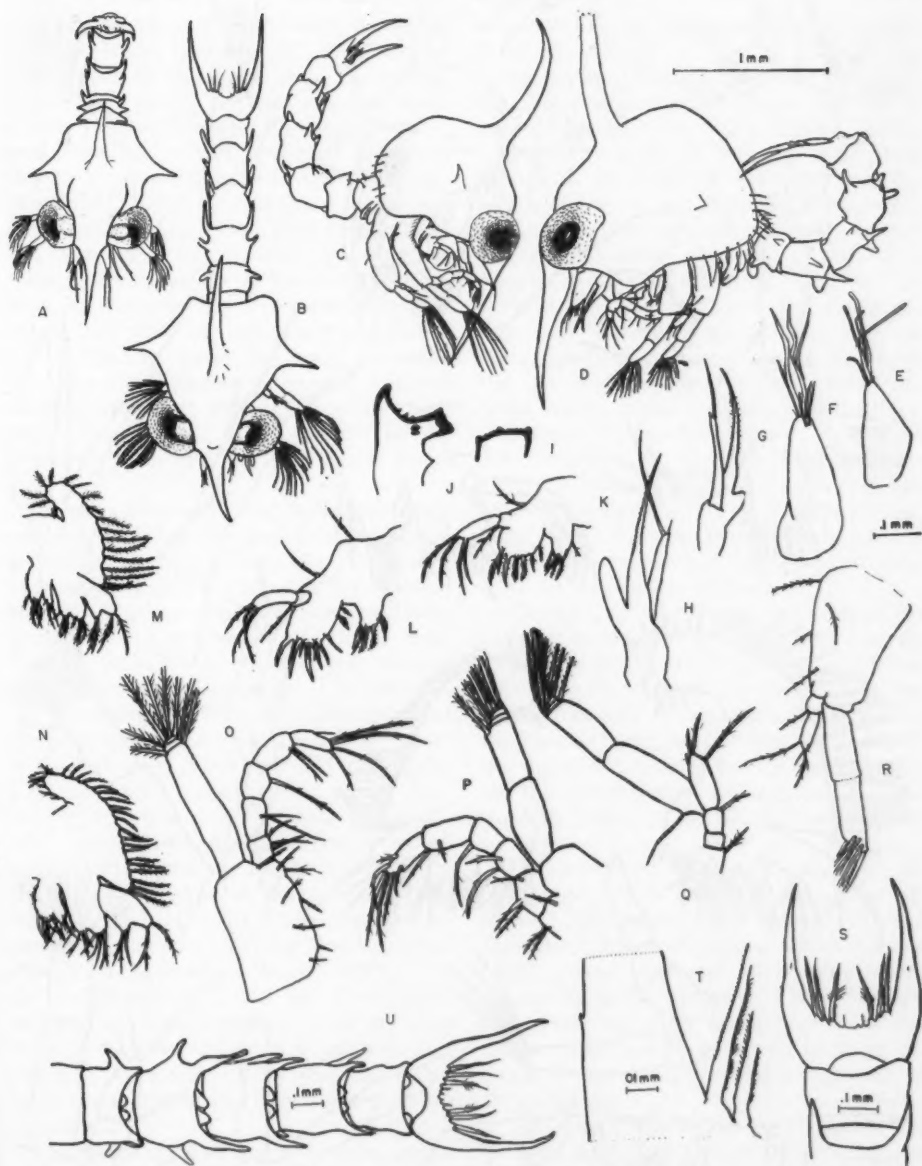


Fig. 2.—Third and fourth zoeal stages of *Menippe mercenaria*. A, dorsal view of third stage; B, dorsal view of fourth stage; C, lateral view of third stage; D, lateral view of fourth stage; E, antennule of third stage; F, antennule of fourth stage; G, antenna of third stage; H, antenna of fourth stage; I, lateral cutting edge of third-stage mandible; K, maxillule of third stage; L, maxillule of fourth stage; M, maxilla of third stage; N, maxilla of fourth stage; O, first maxilliped of third stage; P, first maxilliped of fourth stage; Q, second maxilliped of third stage; R, second maxilliped of fourth stage; S, telson of third stage; T, part of ramus of third-stage telson; U, ventral view of fourth-stage abdomen. Scale of whole zoea indicated by the 1 mm line. Scale of zoeal parts, unless otherwise indicated, shown by 0.1 mm line.

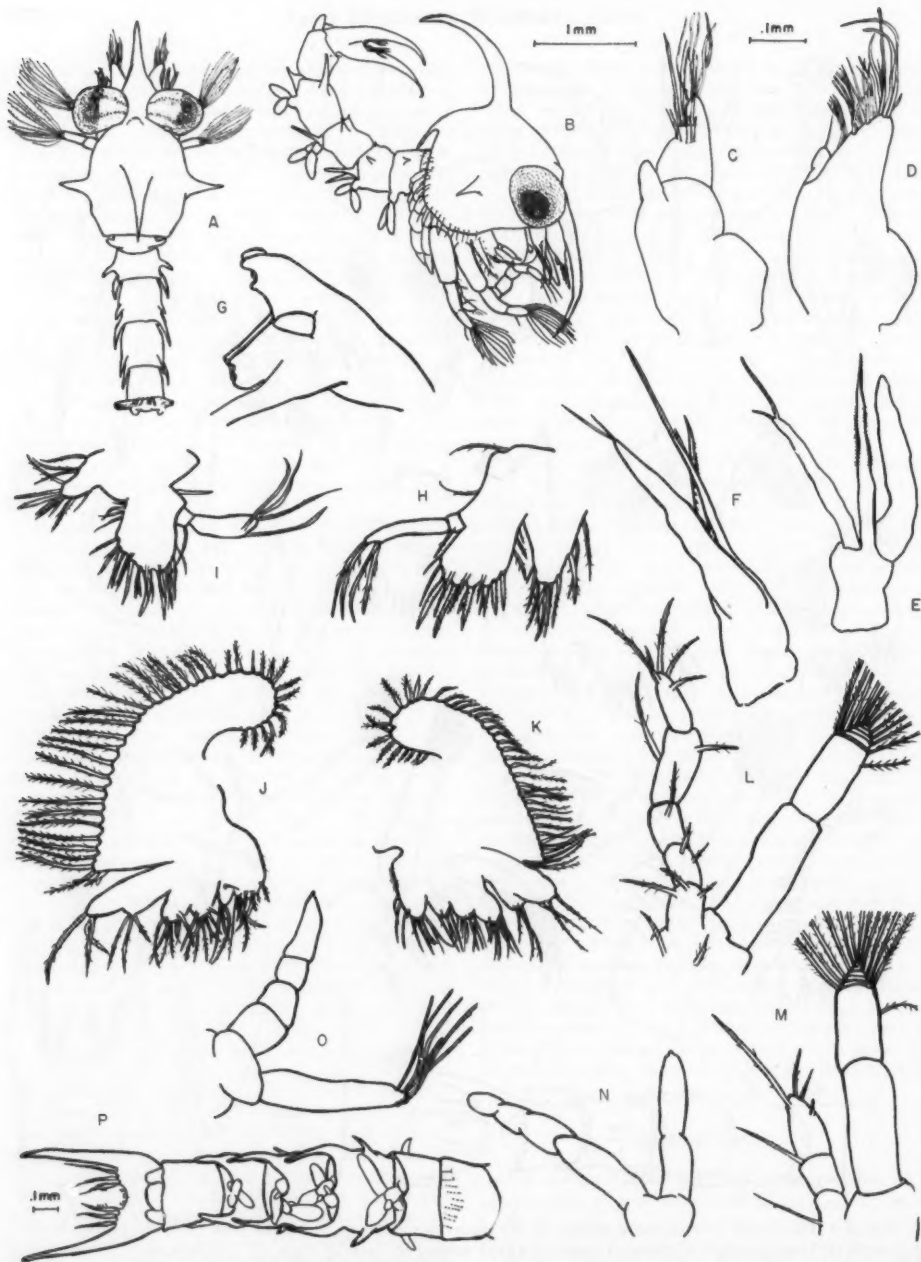


Fig. 3.—Fifth and sixth zoeal stages of *Menippe mercenaria*. A, dorsal view of fifth stage; B, lateral view of fifth stage; C, antennule of fifth stage; D, antennule of sixth stage; E, antenna of fifth stage; F, antenna of sixth stage; G, anterior view of fifth-stage mandible; H, maxillule of fifth stage; I, maxillule of sixth stage; J, maxilla of fifth stage; K, maxilla of sixth stage; L, first maxilliped of fifth stage; M, second maxilliped of fifth stage; N, third maxilliped of fifth stage, epipodite not shown; O, third maxilliped of sixth maxilliped; P, ventral view of abdomen of fifth stage. Scale of whole zoea indicated by the 1 mm line. Scale of zoeal parts unless otherwise indicated, shown by 0.1 mm line.

after hatching into first-stage zoeae by Hyman (1925). Chamberlain (1957) stated that zoeae of the mud crab, *Neopanope texana*, shed from a pre-zoea to a first stage within five minutes after hatching. Costlow and Bookhout (1959) reported that, although a pre-zoeal stage is known for the blue crab, *Callinectes sapidus*, the larvae were found to hatch from eggs directly into first-stage zoeae. In this study some *Menippe* zoeae in the first stage were collected within seconds after hatching. Pre-zoeae have been noted most often in cases where the viability of hatching zoeae was poor; pre-zoeae placed in watch glasses were never observed molting into a first stage. It is possible that the pre-zoeal stage is not normal in the planktonic existence of the larval stone crab.

On the other hand, the sixth stage may not be a true stage but may be an advanced fifth stage as suggested by observed variability of its character and since none molted into the megalops stage. Costlow and Bookhout (1959) observed an additional zoeal stage in the blue crab which usually did not molt into a megalops stage. Furthermore, the endopodite bud of the antennule and the palp bud of the mandible which appear in the last stage (fourth) of the mud crabs, *Lophopanopeus bellus* (Hart, 1935), *Neopanope texana sayi* and *Xantho* (Hyman, 1925) and *Rhithropanopeus harrisi* (Connolly, 1925) appear on the fifth zoeal stage of *Menippe mercenaria*. A branch on the antennule in the fourth stage was also reported by Lebour (1922) for *Xantho incisus* and *Pilumnus hirtellus*. Broad (1957), Costlow and Bookhout (1959) and Rees (1959) pointed out that the number of larval stages for a particular crustacean is not constant and may be influenced by diet and other factors not only in the laboratory but also in nature.

The tendency of dorsal and rostral spines of the carapace to become proportionately longer than the lateral spines also occurs in *L. bellus* (Hart, 1935). In *M. mercenaria* and *L. bellus* the setae counts on the posterior margin of the cephalothorax of the first, second and fourth stages are similar. These counts are also similar for the first three

zoeal stages of *M. mercenaria* and *R. harrisi* (Connolly, 1925).

One of the diagnostic characteristics of the *Menippe* zoea is the shape and size of its antenna (Hyman, 1925; Aikawa, 1937). Characteristically, the antenna is medium sized with its exopodite about one-half the length of the protopodite. The total length of the antenna is about one-half that of the rostral spine throughout the zoeal stages. *Actumnus setifer*, *P. hirtellus*, *P. spinifer*, *P. villosus*, *P. minutus*, *P. vesperilio* and *Heteropanope globula* may be separated from *Menippe* by the length of the antenna protopodite and exopodite being nearly equal (Aikawa, 1929; 1937). Other xanthids, as for example: *X. incisus*, *X. hydrophilus*, *X. exasatus* (Aikawa, 1929; 1937), *N. texana sayi*, *Eurypanopeus depressus* (Hyman, 1925) and *R. harrisi* (Connolly, 1925), have antennae consisting of a long protopodite with a short spine or exopodite on their proximal end.

Aikawa (1937) demonstrated the maxillule endopodite count of 4-1 setae to be a useful diagnostic character, and that this formula appears in the xanthids, *Sphaerozium nitidus*, *P. villosus* and *P. minutus*. Costlow and Bookhout (1959) did not find the count of the endopodite setae to be constant throughout the larval stages of *C. sapidus*. I found the setae count of the maxillule endopodite to be constant.

The bifurcated endopodite count of the maxilla at 3-3 is constant throughout all stages. This count also appears on the Japanese xanthid, *S. nitidus*, which Aikawa (1937) placed in closest relationship to *M. mercenaria* in his grouping. The bifurcated basis and coxa show no increase until the fourth stage and then not so large an increase as appears in the basis and coxa of the maxillule.

The setae formula for the endopodite of the first maxilliped changes little during its zoeal history. In the first and second stages it is 5-2-1-2-2, in the third stage it is 5-2-1-2-3 and in the fourth, fifth and sixth stages it remains at 6-2-1-2-3. The numbers of setae on the protopodites of both first and second maxillipeds appear to remain constant during all zoeal stages.

The setae formula for the endopodite of the second maxilliped is 4-1-0 throughout all zoeal stages. Aikawa (1937) shows that absence of any setae on the basal segment of the endopodite helps distinguish *Menippe* and *Sphaerozius* from other closely related species.

The sixth abdominal segment is separated from the telson of the stone crab zoea in the third stage as in the xanthids described by Connolly (1925), Hart (1935), Hyman (1925) and Lebour (1922). The pair of setae on the posterior dorsal surface of each abdominal segment occurs in the same location on the second through the fifth segments of *R. harrisi* (Connolly, 1925). The description of the pleopods of *M. mercenaria* in the fifth zoeal stage fits that of the pleopods of *R. harrisi* in the fourth zoeal stage.

Aikawa (1937) cited the presence of two small spinules on the outer surface of the telson fork as one of the diagnostic characters for *Menippe*. These spinules are quite small and seen only with difficulty. It was not possible, for example, to find them on all preserved specimens in this study.

Up to five small setae appear in the last zoeal stage on the median surface of the telson. Lebour (1922) apparently was in error in stating that the lack of extra pairs of internal setae on the telson is one of the characteristics of the subfamily Menippinae.

Chromatophore presence, checked for in the first zoeal stage only, agrees with Hyman (1925) with the following exceptions: no anterior rostral chromatophore was seen and a chromatophore was seen near the base of the antennule. As shown further by Hyman (1925), the presence of chromatophores on the dorsal spine may be one of the identifying characters separating *Menippe* from other xanthids.

The salinity and temperature studies indicate that in the 27 to 30°C range a few zoeae are capable of attaining a fifth stage in salinities as low as 23‰. In a temperature range of 23 to 25°C the larvae may not be able to do this in waters 27‰ or below. The expectation is that the best environmental conditions for *Menippe* larvae would be in warm, high salinity waters, since the north-

ern limit of its range is North Carolina in a high salinity habitat.

Conclusions

1. Larvae of the stone crab, *Menippe mercenaria* Say, can be reared from egg to a true crab stage in the laboratory in about 27 days using *Artemia* nauplii as food.

2. Normal zoeal development consists of five stages. A pre-zoeal and a sixth stage are sometimes seen.

3. The following parts, because of their stability throughout all zoeal stages, are useful in larval identification: comparative lengths of dorsal or rostral spines and antennae, comparative lengths and shape of protopodite and exopodite of antennae, segment numbers and setae numbers of endopodites of maxillules, maxillae and second maxillipeds. Telson shape and chromatophore occurrence may also be useful in identification.

4. Preliminary evidence indicates a need for warm water of high salinity for optimum survival of larvae.

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Chesapeake Bay Hurricane Surges

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ABSTRACT

Storm surges of hurricanes passing west of Chesapeake Bay are compared to surges generated by hurricanes passing east of the bay. The surges of each type storm are quite different, as the western storms cause highest surges in the northern portion of the bay and the eastern storms produce highest surges in the southern portion.

Introduction

Although the hurricane tides of Chesapeake Bay do not attain the proportions of those that occasionally occur in other areas, they are nevertheless important. Piers, wharves, buildings, fishing and pleasure boats have been damaged, the shoreline has undergone accelerated erosion and farmland has been flooded. The most destructive hurricane affecting Chesapeake Bay (August 1933) caused an estimated \$17,000,000 damage in the area, according to the U. S. Army Corps of Engineers (1956).

This study was undertaken to show qualitatively the dependence of the storm tide upon the path of the hurricane. The storm tides of hurricanes passing near but east of the bay are compared to the tides of those passing near but west of the bay and it is found that the tides of each type storm fit a definite pattern, significantly different from each other.

The data examined are values of the storm surge, defined as the difference between the observed storm tide and the predicted astronomical tide. The height of the actual tide depends upon the phase of the predicted tide during storm surge conditions as well as the storm surge. A given storm surge will have more practical importance if it occurs at time of predicted high tide rather than at time of predicted low tide.

GENERATION AND MODIFICATION OF THE STORM SURGE

Among storm surge generation and modification factors (Harris, 1956; and Hubert and Clark, 1955), the following are considered significant in Chesapeake Bay:

1. Wind set-up, which is the result of wind stress on the surface of the water, the stress being proportional to the square of the wind speed and inversely proportional to the water depth.

2. The transport of water in the direction of wave motion by the short period wind waves, resulting as the water particles advance at a slightly higher speed at the top of the particle orbit.

3. The atmospheric pressure effect, often called the inverted barometer effect, which is the rise of the water surface in the area of minimum atmospheric pressure (approximately 13.6 inches of water per inch of mercury pressure drop).

4. The storm speed, which enters into dynamic amplification of the storm surge due to resonance between the natural frequency of the bay and the storm surge.

5. The variable depth of the water, resulting in modification of the surge as it progresses in the bay, similar in manner to the shoaling effect of bathymetric conditions on short period wind waves.

6. Convergence or divergence of the storm surge, a modification important at locations such as in estuaries of varying width.

THE DATA

The 35 hurricanes that came close enough to the bay from 1929 through 1958 to be suspected of producing storm surges were investigated. The storm surge features of several of these storms are shown in Figs. 1-5. The hydrographs show the difference between the actual storm tide as recorded by the Coast and Geodetic Survey recording tide gages and the predicted astronomical

tide, based on hourly values of both the observations and predictions. The seasonal anomalies in sea level have been removed from these data by the method described by Harris (1959). The dotted portions of several of the hydrographs indicate estimated data during periods of malfunctioning tide gages. The small triangles above and below the hydrographs for Baltimore and Hampton Roads respectively give the times of high or low predicted astronomical tide as taken from the Tide Tables (U. S. Coast and Geodetic Survey (1955)). Some of the hydrographs are supplemented with wind observations from nearby weather stations. The storm paths, 12 hour positions and storm stages were obtained from Cry, et al., (1959). The inserted barometric pressure charts show some of the synoptic features of the storms while they were in the bay area.

The maximum storm surges will occur only by coincidence at tide gage locations. However, the gage records are useful for comparing the surges of various storms.

Dependence of Storm Surge upon Hurricane Path

It is not surprising that hurricanes which pass on opposite sides of Chesapeake Bay would produce storm surges of different characteristics because of the resulting opposite wind directions over the bay. Hurricanes which passed west of the bay, east of longitude 80° W., but not crossing over it were classed as the western type (Figs. 1 and 2), whereas those that passed east of the Bay but west of the points 35° N., 73° W. and 40° N., 68° W., proceeding in a north or northeast direction were of the eastern type (Figs. 3 and 4).

The storm surges of the western type storms progress from the mouth to the head of the bay with the magnitude of the surge generally increasing northward. It should be noted that the astronomical tide range decreases from the mouth to head of the bay. This is in contrast to the situation when hurricanes pass just to the west of Narragansett Bay, where the storm surge heights in various parts of the bay are proportional to the mean tide range.

The storm surge heights of the western

type storms are given in Table 1 along with the time lag for the surge to travel from Hampton Roads to Baltimore and the 12 hour northward movement of the storm while in the bay area. In each of these storms the highest surge occurred at Baltimore. A lag in the surge from Hampton Roads to Baltimore of about 11 to 21 hours occurs with a slight inverse relationship between this lag and the northward movement of the storm.

Two peaks in the storm surge at Baltimore and Annapolis accompany about half of the western type storms. The first occurs near the time of storm passage and the second from 4 to 7 hours later. Sufficient data are not available to confidently determine the reason for the two peaks.

As the storms of the eastern type approach northerly wind components build up the surge in the southern part of the bay. During most of these storms the surge level drops in the northern part of the bay because of the northerly winds, with the most pronounced drop at Baltimore and almost as much drop at Annapolis. Table 2 is a tabulation of the eastern type storm surges and shows the maximum surge to occur in the Norfolk area, quite opposite to the maximum surge location of the western type storms. The initial drop at the northern stations is shown by the negative values in the table.

OTHER STORMS

Hurricane Connie of 1955 (Fig. 5) is somewhat between the two types discussed above, as its path approximately coincided with the axis of the Chesapeake Bay. The resulting surge at Baltimore of 5.4 feet was surpassed only by the 7.0 surge of the August 1933 storm. A rise in the surge curve, which appears to have been caused by the increase in the onshore wind component over the ocean near the mouth of the bay and over the bay itself about 12 hours before storm passage, preceded the main surge at all stations and was most prominent at the southern stations.

The inverted barometer effect was more important for Connie than for the other storms because the storm center passed near the axis of the bay. The recorded mini-

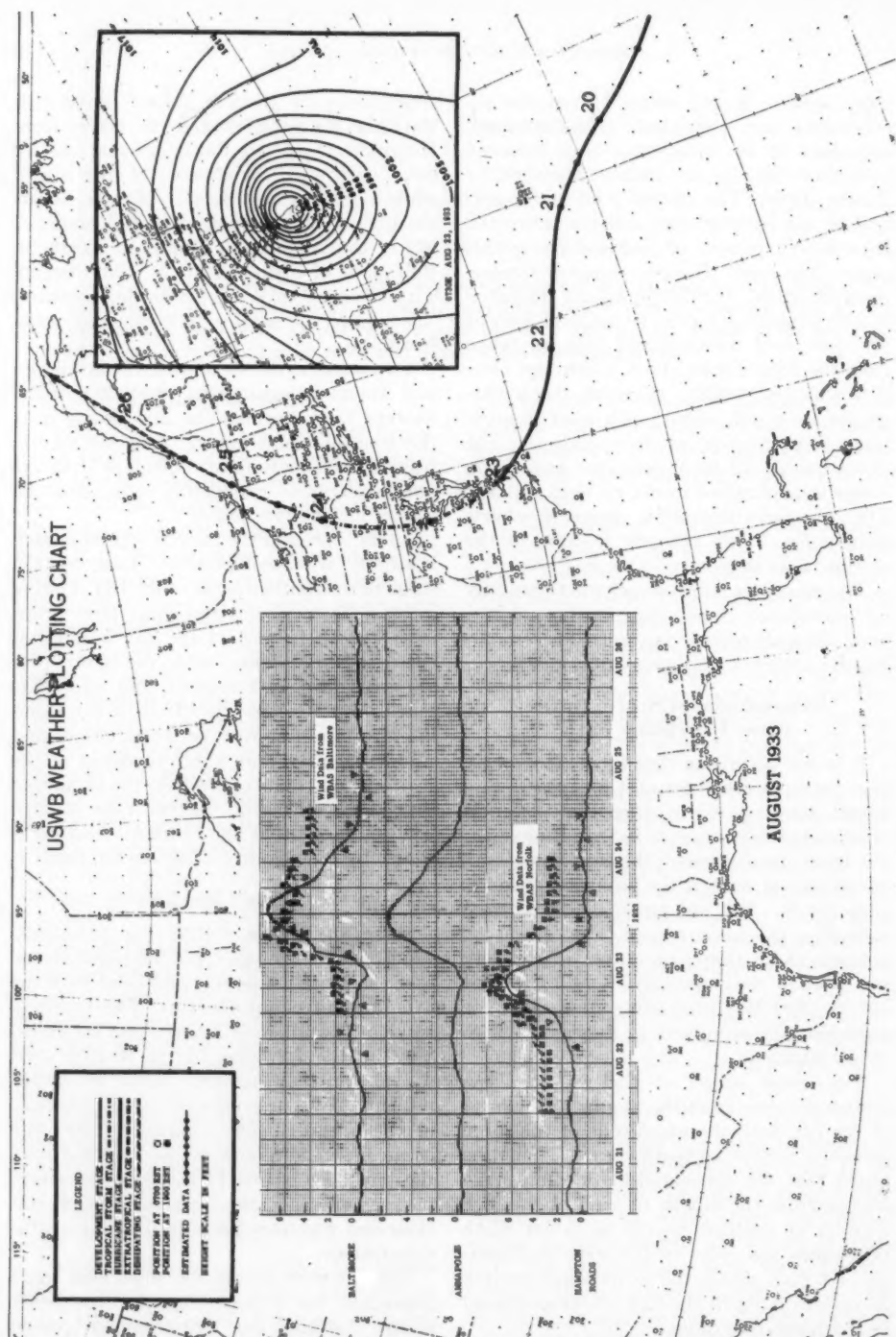


FIG. 1.—Storm surge of August 23-24, 1933. Hydrographs show differences in feet between observed tide and predicted astronomical tide. Insert shows the surface pressure pattern with isobars labeled in millibars.

TABLE 1.—Storm surge data of western type storms in the Chesapeake Bay region. Heights of the peak surge are expressed in feet and corrected for the seasonal anomalies in sea level.

Date	Baltimore	Annapolis	Cambridge	Solomons	Gloucester Point	Hampton Roads	Time Lag Norfolk to Baltimore (Hours)	Twelve Hour Northward Storm Movement (Nautical Miles)
Oct. 2, 1929	3.9	3.6	—	—	—	2.4	18	190
Aug. 23, 1933	7.0	5.5	—	—	—	6.1	18	170
June 19, 1934	—	—	—	—	—	0.8	—	80
Sep. 18, 1945	2.7	2.4	2.3	2.1	—	2.4	17	210
Aug. 29, 1949	1.7	1.4	1.5	0.8	—	-0.2	—	280
Sep. 1, 1952	3.4	2.9	—	1.6	0.5	0.4	13	130
Oct. 15, 1954	4.6	3.9	—	2.8	1.1	1.5	11	510
Aug. 18, 1955	2.9	2.4	—	1.7	1.7	1.0	21	130

TABLE 2.—Storm surge data of eastern type storms in the Chesapeake Bay region. Heights of the peak surge are expressed in feet and corrected for the seasonal anomalies in sea level. The negative values are the initial drops in storm surge at the northern stations.

Date	Baltimore	Annapolis	Cambridge	Solomons	Gloucester Point	Hampton Roads	Portsmouth
Sep. 21, 1938	-3.2, 0.2	-2.2, 0.1	—	-1.4	—	—	1.8
Sep. 1, 1940	0.2	0.2	—	0.2	—	—	0.3
Aug. 20, 1950	0.7	0.7	0.5	0.6	—	0.8	—
Sep. 27, 1956	1.1	1.9	—	2.1	—	3.7	—
Aug. 28, 1958	-1.2, 0.6	—	—	0.6	—	1.1	—
Sep. 14, 1944	-2.1, 0.9	-1.6, 0.7	-0.9, 0.8	-0.6, 0.6	—	3.7	—
Aug. 14, 1953	-2.6, 1.3	-2.4, 1.1	—	-1.5, 1.1	3.1	3.7	—
Aug. 31, 1954	-0.6, 0.7	0.8	—	0.8	1.6	2.6	—
June 26, 1945	-1.1, 0.6	-0.8, 0.8	-0.6, 0.9	0.5	—	2.6	—
Sep. 8, 1934	—	—	—	—	—	0.8	—
Sep. 18, 1936	-5.7, 1.3	-4.2, 1.2	—	—	—	4.9	—
Sep. 16, 1933	0.9	1.0	—	—	—	5.1	—
Oct. 24, 1938	0.7	0.7	—	0.6	—	—	0.7
Sep. 11, 1954	-1.4, 0.5	-1.0, 0.4	—	-0.4, 0.5	2.2	2.9	—

imum pressure at both Baltimore and Patuxent (Naval Air Station) was 975 mb or 35 mb below the average Baltimore pressure for that month which amounts to a barometric effect of 1.2 feet.

Another effect important for Connie was the amplification due to resonance between the Bay and the storm surge. From Proudman (1953), where C is the storm speed

$$\text{Amplification} = \frac{1}{1 - \frac{C^2}{V^2}}$$

(about 13 knots for Connie) and V is the free wave velocity. Estimating the free wave velocity from the speed of the astronomical tide in Chesapeake Bay, one obtains a value of 17 knots. The value agrees with the aver-

age speed of the main storm surge between Hampton Roads and Baltimore. These values give an amplification of 2.4.

Several storms did not fall into either of the two categories and did not produce significant surges in Chesapeake Bay.

Conclusions

Many of the hurricanes affecting Chesapeake Bay can be classified as being one of two distinct types, depending on whether the storm passes to the east or west of the bay. The resulting storm surges of each type are quite similar to each other but distinctively different from those of the other type, with those passing west of the bay producing the highest surges in the northern bay and those passing east of the bay producing maximum surges in the southern bay.

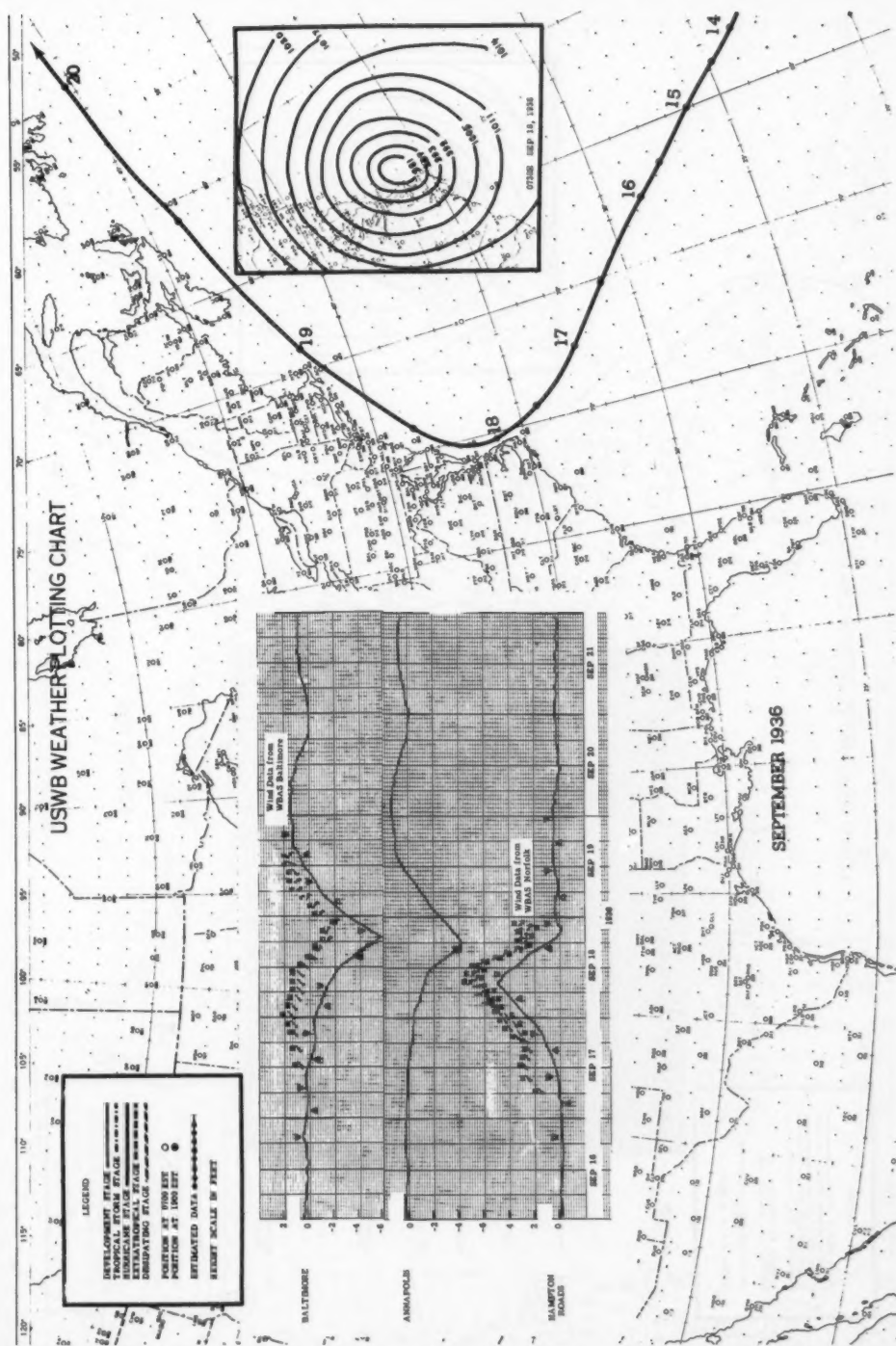


FIG. 3.—Storm surge of September 18-20, 1936. Hydrographs show differences in feet between observed tide and predicted astronomical tide. Insert shows the surface pressure pattern with isobars labeled in millibars.

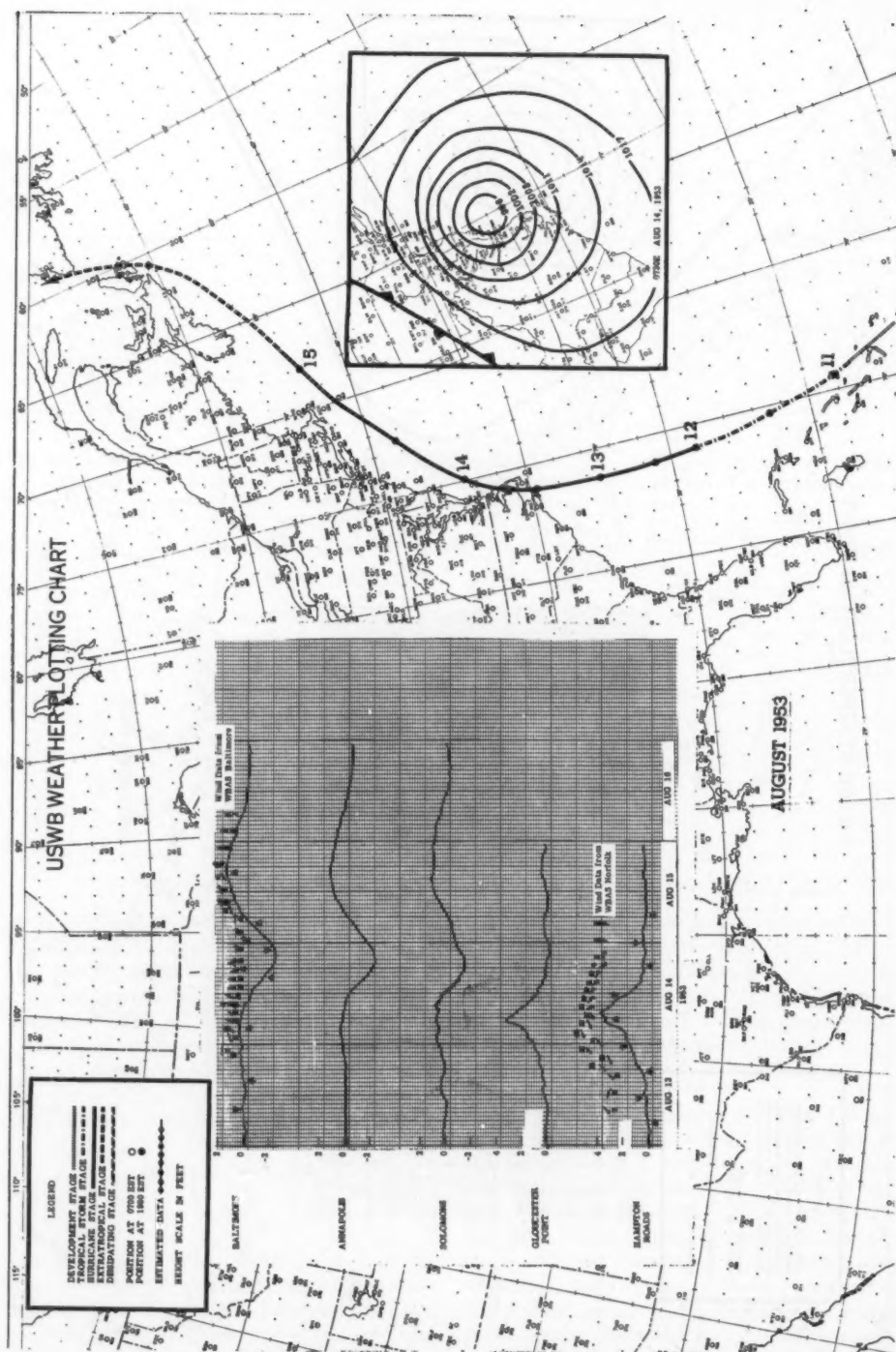


FIG. 4.—Storm surge of August 14–15, 1953. Hydrographs show differences in feet between observed tide and predicted astronomical tide. Insert shows the surface pressure pattern with isobars labeled in millibars.

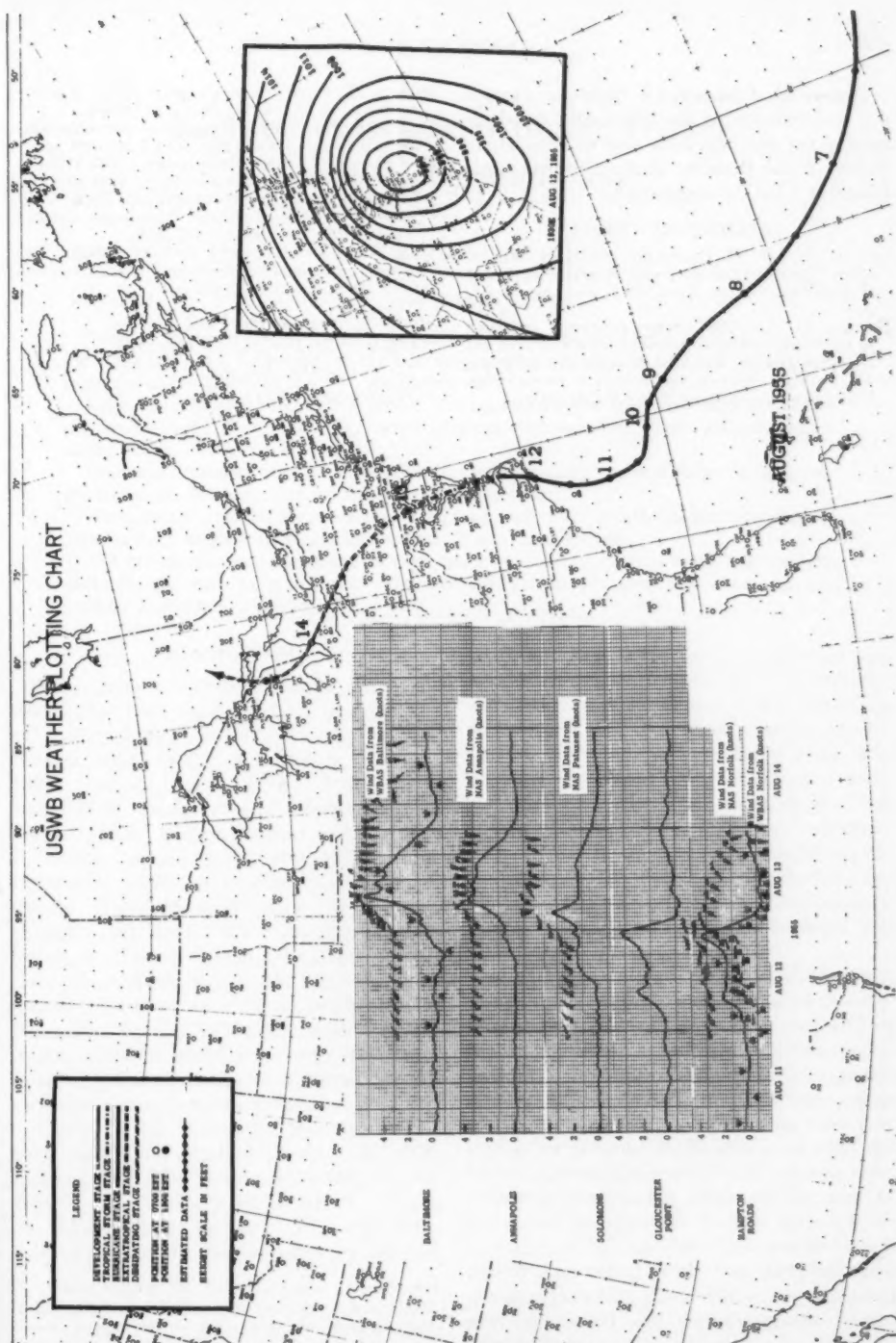


FIG. 5.—Storm surge of August 12-13, 1955. Hydrographs show differences in feet between observed tide and predicted astronomical tide. Insert shows the surface pressure pattern with isobars labeled in millibars.

Acknowledgment:—I wish to express my appreciation to the Coast and Geodetic Survey for the tide data and to Mr. D. L. Harris of the Weather Bureau Storm Surge Research Unit for suggestions.

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Larval Development of the Oyster Toadfish, *Opsanus tau*¹

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ABSTRACT

Detailed illustrations of the early larval development of the oyster toadfish, *Opsanus tau* (Linnaeus), are presented for the first time to show variation in size and morphology, sequence of fin formation and yolk absorption.

Eggs, 5 mm in diameter, were attached to a substrata by an adhesive disk and hatched into larvae about 7.0 mm T.L. They were studied through essentially prolarval growth until about 19.0 mm T.L. and 20 days old.

Prominent features were the large stalk-like yolk sac and a pectoral-pelvic fin apparatus position shift. The color pattern was apparent at 16.4 mm.

Head, snout-anus and eye lengths compared with total length showed proportional growth. Body depth-total length showed non-proportional growth.

The full complement of various fin rays was apparently attained at these total lengths: pectoral—17.1 mm; spinous dorsal—10.8 mm; soft dorsal—12.8 mm; anal—12.8 mm; and caudal—probably at 18.0 mm.

Introduction

The oyster toadfish, *Opsanus tau* (Linnaeus), has been used widely in morphological, embryological and experimental studies (Clapp, 1891, 1899A, and 1899B; Wallace, 1899; Sumner, 1903; Tracy, 1910, 1925, 1926, 1959; Lazarow and Berman, 1947; Fodden, 1956; Wilber, 1958; Tavalga, 1958; Robinson, et al., 1960; and Wilber and Robinson, 1960). It ranges in estuarine waters from Massachusetts to Florida (Schultz and Reid, 1937:212), is easily collected, and hardy under laboratory conditions. Reproduction and the early development of the oyster toadfish are easily studied (Costello, et al., 1957:233), and for this reason will undoubtedly serve in the future as an important source of material for descriptive and experimental studies.

The early life history of this species has been extensively studied (Storer, 1867:105; Agassiz, 1882:279; Goode, 1884:252; Ryder, 1886:77-80, 1887:4-8, 1890:407-8; Clapp, *op. cit.*; Wallace, *op. cit.*; Gill, 1907:399), culminating in the classic paper by Gudger

(1910:1071-110). He used, interpreted and integrated earlier published information with his own observations which were supplemented with some interesting photographs, but which did not show detail. Except for the recent work of Tracy (1959), his work on early larval development has not been extended significantly, especially with regard to meristic and morphometric changes. Observations made during the present study, both qualitative and quantitative, have corroborated his general observations.

Most of the references cited above contained rather complete and detailed descriptions but few illustrations. The majority of the latter, however, were incomplete or inadequate to show ontogenetic development of the prolarvae, postlarvae and very young stages. Accordingly, the following contribution is an attempt to fill this void with detailed illustrations and brief descriptions with reference to the other studies and to point out avenues for further research on and use of the species. This study is primarily concerned with the morphological changes that take place during the prolarval growing period and metamorphosis to the young stage.

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The author is greatly indebted to Dr. Romeo Mansueti for his technical guidance and editorial assistance, to his wife, Alice Jane Mansueti, for her professional artistic advice, and to Mr. Malcolm Taylor and Mr. Grover Butz for their assistance in collecting and recording the necessary information. Suggestions and comments of the paper by Dr. Charles Wilber and Mr. Paul Robinson were helpful in the final preparation of this report. Dr. W. R. Taylor kindly provided vertebral counts of toadfish in the U. S. National Museum.

Methods and Materials

This study is based on two groups of toadfish eggs: (a) 50 toadfish eggs collected in an old tin can in shallow water on July 22, 1960 in the lower Patuxent River near the Chesapeake Biological Laboratory, Solomons, Calvert County, Maryland; and (b) 40 eggs collected from the same area on August 1, 1960. These eggs, averaging about 5 mm in diameter, contained well-developed embryos similar to that of Fig. 1. The process of egg-laying and hatching in nature was not studied in great detail since this information is well documented in the literature. The developing larvae were observed in fingerbowls in the laboratory where temperatures between 68–70°F were maintained.

Two specimens from the first group were studied and illustrated in great detail as they developed. All illustrations, except Fig. 1 and 8, were made from these two larvae. Fig. 1, 8, 13A, B, and C, and Table 1 were derived mostly from fish from the second group of eggs, which was used primarily for meristic and morphometric measurements and to verify observations made on the two specimens. Although the eggs were studied, no effort was made to illustrate and describe these stages except for a late embryonic stage (Fig. 1). Body measurements were taken according to criteria given by Hubbs and Lagler (1958:19–21). Total length is abbreviated as T.L. Fin ray counts were made under 12× magnification and are given as the total number of principal rays observed before and in some cases after dissection, except for the caudal fin. The problem of caudal fin ray counts is discussed under "Results."

Illustrations were sketched and measured from live material under a 12× magnification with the aid of a stereoscopic binocular microscope. Finished drawings were about 20×. Most specimens were either refrigerated no more than 10 minutes or held in containers of ice water to slow down activity in order to facilitate observation. Each specimen was carefully measured and proportional measurements were checked to insure accuracy of rendition.

The results of this report are correlated with those of Tracy (1959), who began his studies with two earlier papers (Tracy, 1925 and 1926). The two works overlap to the extent that Figs. 1–12 in this work can be compared with the last four stages of larvae that he described. He designated eight developmental stages in the developing motility of toadfishes, beginning with fertilization and continuing through larval development to the point at which the larvae were capable of adult actions and reactions. He terminated the study when the larvae had grown to approximately 14 mm in length.

Results and Discussion

GENERAL OBSERVATIONS

The toadfish nest is situated in cavities among shells or rocks, but most often in old tin cans, broken bottles and other artificial sites near human habitation. In Chesapeake Bay region, data gathered for this study indicate that the spawning season ranges from April to July, rather than from April to October, as stated by Hildebrand and Schroeder (1928:337). The comparatively large eggs are adhesive to natural or artificial substrata. The newly hatched prolarvae remain attached by an adhesive disk until the yolk sacs are completely absorbed. During this time the adult male guards the eggs and young. When about 16 mm in length the young toadfish, having acquired most of the adult features, begin feeding and break from the nest as free swimmers.

OBSERVATIONS ON THE LARVAE

Fig. 1 illustrates a late embryonic stage shortly before hatching. At this point the embryo was approaching complete somite formation and, according to Tracy (1959:

45), would be capable of the "C and S coil" movements "when the capacity to contract has caught up with the last somites." This stage compared well with late stage 5 as described by Tracy.

Fig. 2 represents a recently hatched prolarva (7.4 mm T.L.) which hatched two days after collection of the eggs on July 22. Due to the unusually large size of the yolk sac in comparison to the body, the newly hatched larvae appeared to be perched atop a gigantic mass. Gudger (1910; plate CXI, Fig. 9) showed how newly-hatched young normally appear on a *Pinna* shell. The chorion remained generally in place following the process of hatching but was irregular and crumbled at the edges. The latter condition could have been due to increased larval activity or hatching enzymes (Smith, 1957: 353).

The larvae were generally transparent at this stage but presented very little definition in the head region. It was possible, however, to define the transparent eye, the rudimentary mouth parts, the posterior edge of the operculum and the general outline of the brain lobes. The vertebrae and myotomes could be counted only behind the pectoral and pelvic fins which remained much as lateral buds. Counts anterior to the pectoral were impossible. The dorsal, caudal and anal fins were present in the form of a continuous fin fold as shown in Fig. 2. Blood circulation was easily observed over the surface of the yolk sac and through some areas of the body tissue. This specimen (7.4 mm), only a few hours old, was somewhat larger than the published size range at hatching, i.e. 5 mm (Tracy, 1910:149; and Ryder, 1887:8, Fig. 2) to 7 mm (Tracy, 1959:46).

There seems to be considerable confusion in the literature concerning the size and degree of development at hatching, since very few references provide accurate measurements of hatching sizes. Agassiz (1882: 279, plate 16) illustrated an 8 mm free-swimming stage caught in a plankton net, which Ehrenbaum (1909:46) and Tracy (1910:46) questioned as inaccurate. The results of this study also suggest that Agassiz's figure did not represent a toadfish. The reference by Agassiz (1882:279) to a draw-

ing of a young toadfish 2 mm long in Storer (1867: plate 19) is also in error. The copy of this reference owned by Dr. R. Mansueti does not give a size for the figure, except to cite "nat. size" for a $3\frac{5}{16}$ inch specimen possessing most of the adult features. The drawing by Ryder (1887:8, Fig. 1), reproduced in Bigelow and Welch (1925:357) but not in Bigelow and Schroeder (1953:518-20), showed an 8 mm specimen much more advanced in morphological development and in a color pattern than any similar sized individual observed in the present study. These features did not appear in this study until the larva had grown to 14 or 15 mm in length. Ryder's newly hatched specimen was only 5.5 mm, which is considerably smaller than any hatchlings observed in this study or described elsewhere. Clapp (1899:243, Plate XVIII, Fig. 6) showed a newly-hatched toadfish larva, very stylized in appearance but lacking desirable detail. At 15 \times her specimen was about 12 mm long, a size which was apparently exaggerated for the stage. Gudger (1910:1102) further criticized her drawing for its lack of a mouth, gill slits and the incorrect position of the tail. In summary, these references suggest that there may be considerable variation in the hatching size, but that the extreme lengths recorded are unexplained at this time.

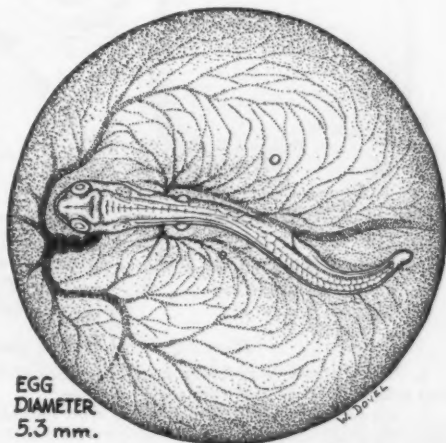


Fig. 1.—Late embryonic stage of the oyster toadfish, *Opsanus tau*. Diameter of egg—5.3 mm; and length of embryo—5.1 mm.

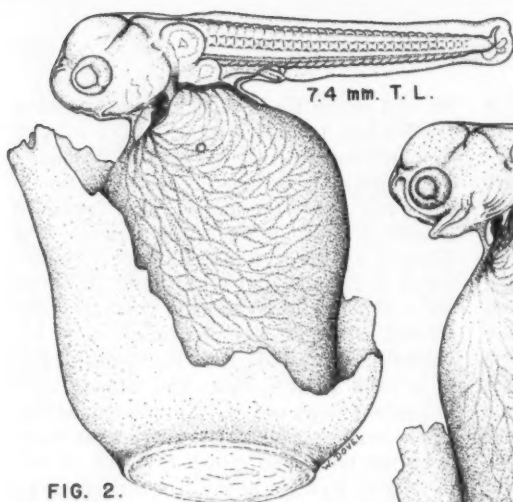


FIG. 2.

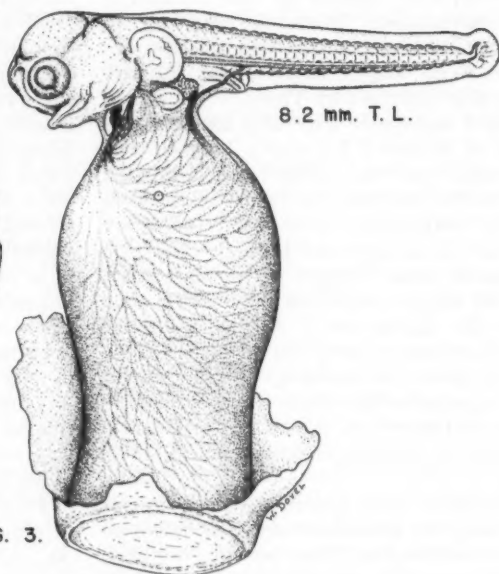


FIG. 3.

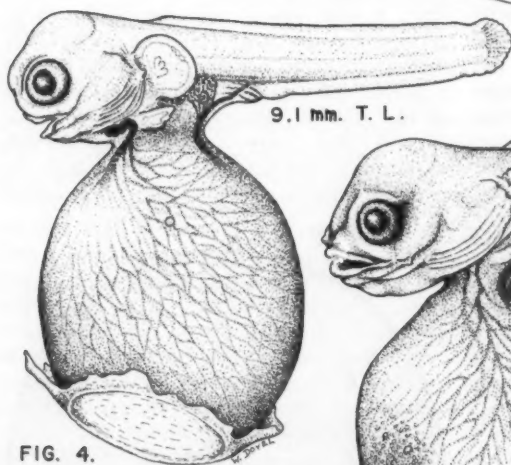


FIG. 4.

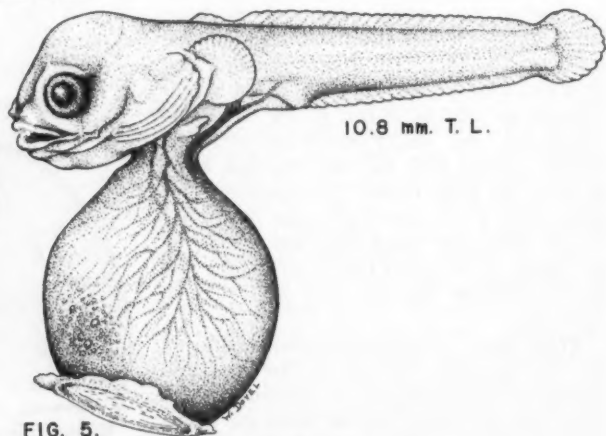


FIG. 5.

Figs. 2-5.—Prolarvae of the oyster toadfish, *Opsanus tau*.

2. Newly hatched prolarva approximately 24 hours after hatching. Length of prolarva—7.4 mm; and height of larva and yolk stalk—7.8 mm.

3. Approximately 48 hours (2 days) after hatching. Length of prolarva—8.2 mm; and height of larva and yolk stalk—9.3 mm.

4. Approximately 92 hours (almost 4 days) after hatching. Length of prolarva—9.1 mm; and height of larva and yolk stalk—7.4 mm.

5. Approximately 164 hours (almost 7 days) after hatching. Length of prolarva—10.8 mm; and height of larva and yolk stalk—7.7 mm.

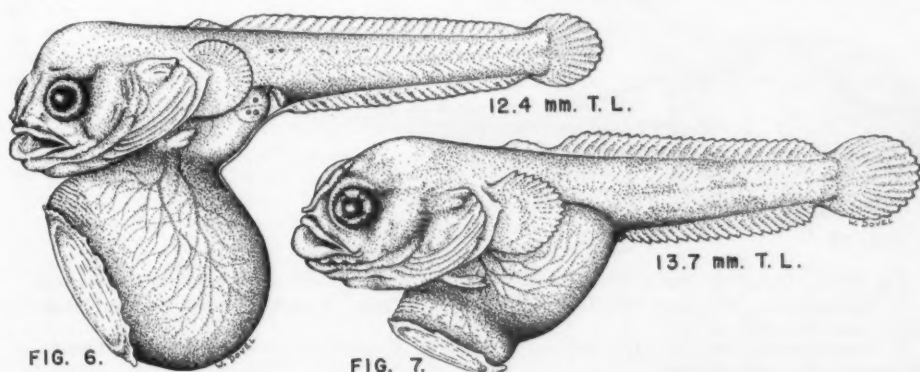
In the specimen illustrated in Fig. 2 the blood flowed in an apparently open system over the surface of the yolk sac anteriorly and dorsally, was gathered by the vitelline vein, as given by Tracy (1959:42), passed through the heart and was pumped posteriorly through the median vitelline artery and over the yolk sac to complete the cycle. Beneath the vertebrae two blood vessels were evident: the dorsal vessel carried the blood posteriorly, while the ventral vessel carried it anteriorly.

Fig. 3 depicts the specimen (8.2 mm T.L.) as it appeared 24 hours later. This stage showed rapid development in the mouth region and a change in the position of the median vitelline artery. Both the heart and vitelline artery had started an upward movement which would eventually locate them within the body cavity. The continual clockwise rotation of the pectoral and pelvic fins, as viewed from the left side, was apparent as was the further development of the caudal fin. Tracy (1959:48) discussed this "clockwise fin rotation" as he observed it in larvae prior to the time of hatching. The mouth and developing operculum were very active in what appeared to be the mechanics of the respiratory system. The larva possessed only a thin scattering of melanophores although the body tissue had become sufficiently opaque as to obscure the internal details.

Fig. 4 shows the larva (9.1 mm T.L.) as it appeared 48 hours following Fig. 3. The greatest changes that had taken place since the last illustration were the further development of the mouth and transition from vertical to more or less horizontal position of the heart. The obvious contractions and expansions of the yolk sacs were, as first pointed out by Gudger (1910:1104), more or less rhythmical. Other slight changes were apparent as this figure was compared with the preceding ones. Larval activity had become very pronounced by this stage.

Fig. 5 shows the larva (10.8 mm T.L.) 72 hours later. At this stage the larva showed a gradual increase in the overall larval development with the most conspicuous features being the disappearance of the heart behind the branchiostegal rays and individual fin ray formation. Gudger (1910: plate CXIII, Fig. 13:1) provided a photograph of a larva close to this stage.

Fig. 6 shows the larva (12.4 mm T.L.) 24 hours later than Fig. 5. This stage was similar to the preceding one but showed in addition the yolk sac pushing upward into the body cavity and the dispersed accumulations of melanophores as the color pattern began to form. Apparently the only explanation available for the upward movement of the yolk was found in an oral communication of Ryder and recorded in Gudger (1910: 1105) to the extent that the yolk sacs of



Figs. 6-7.—Prolarvae of the oyster toadfish, *Opsanus tau*.

6. Approximately 188 hours (almost 8 days) after hatching. Length of prolarva—12.4 mm; and height of larva and yolk stalk—7.2 mm.

7. Approximately 260 hours (almost 11 days) after hatching. Length of prolarva—13.7 mm; and height of larva and yolk stalk—5.3 mm.

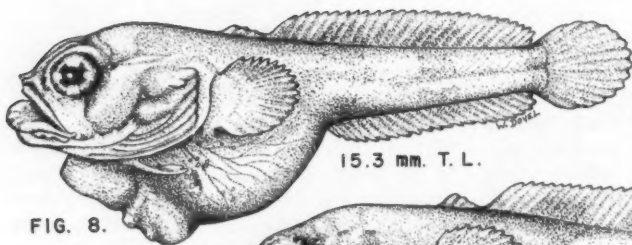


FIG. 8.

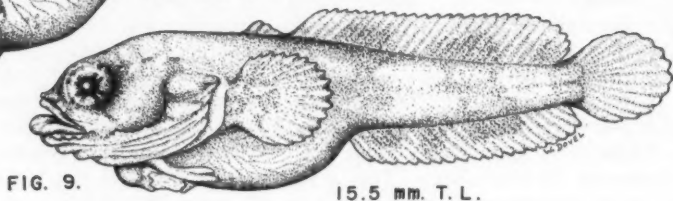


FIG. 9.

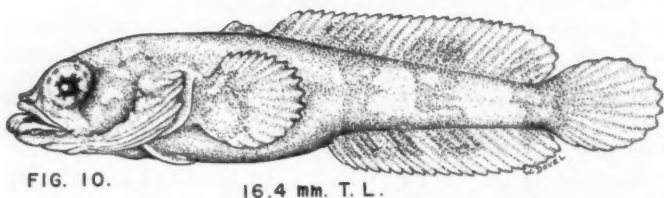


FIG. 10.

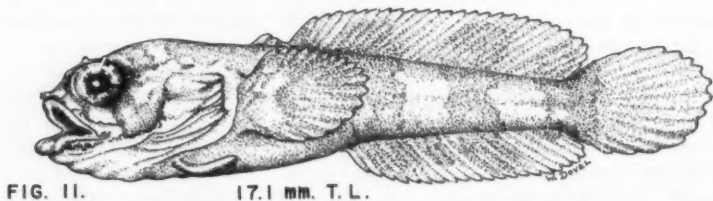


FIG. 11.

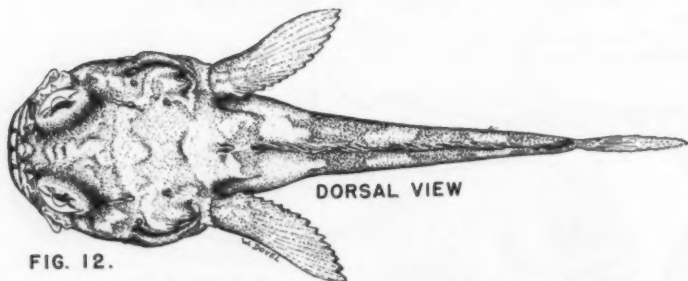


FIG. 12.

Figs. 8-12.—Prolarvae (figs. 8-10) and postlarvae (figs. 11-12) of the oyster toadfish, *Opsanus tau*.

8. Approximately 296 hours ($12\frac{1}{4}$ days) after hatching. Length of prolarva—15.3 mm; and height of larva and yolk stalk—4.6 mm.

9. Approximately 356 hours ($14\frac{3}{4}$ days) after hatching. Length of prolarva—15.5 mm; and height of larva and yolk stalk—4.4 mm.

10. Approximately 400 hours ($16\frac{2}{3}$ days) after hatching. Length of prolarva—16.4 mm; and height of larva and yolk sac—4.2 mm.

11. Postlarva approximately 480 hours (20 days) after hatching. Length of postlarva—17.1 mm; and greatest body depth (behind anus)—4.2 mm.

12. Dorsal view of Fig. 11.

this species are encircled by two layers of spindle-shaped muscle fibers, one running in equatorial fashion, the other at right angles to the first. This explanation, if correct, would explain the driving force behind the yolk's upward movement. For the photograph of a similar specimen see Gudger (1910: plate CXIII, Fig. 13.3).

Fig. 7 shows the larva (13.7 mm T.L.) 72 hours later, and represents the stage at which there was a well-marked delineation between the dorsal, caudal, and anal fins. In addition, the eye possessed the characteristic St. Andrew's cross design of the iris (Gill, 1907:393; Gudger, 1910:1103). The color pattern was forming as was the beginning of the fleshy outgrowth which develops under the mouth.

Fig. 8 (15.3 T.L.) was drawn from the second group of larvae and was used to fill in the gap in development between Fig. 7

and 9. It shows a further degree of yolk absorption. Gudger (1910: plate CXIII, Fig. 13.4) presented a photograph close to this stage.

Fig. 9 through 12 show the gradual accumulation of adult features, with the complete absorption of the yolk sac, approximately 480 hours after hatching. Gudger (1910: plate CXIII, Fig. 13.5-7) showed photographs of comparable stages.

As the specimen being illustrated was detached from the nest, it was impossible to determine at what point it would have become a free-swimming larva. However, two larvae from the second group were observed to break away from their adhesive disk when 18 mm in length. These larvae were slightly larger at this point than those observed by Ryder (1887:358) and Tracy (1910:45). The best evidence from the present study and published reports indicates

TABLE 1.—Measurements and meristic counts of larval toadfish, *Opsanus tau*.

Size Intervals (T.L.) mm	Number of Fish	Average Measurements in Millimeters (Includes 6 Single Measurements)					Meristic Counts							
		Total length (T.L.)	Head length	Eye length	Greatest depth	Snout to anus s/a	Pectoral fin	Pelvic fin	Spinous (first) dorsal	Soft (second) dorsal	Anal soft rays	Caudal fin	Countable myotomes	
													s/a	tot.
7.0-7.5	1	7.36	1.85	0.63	7.76	3.85	LP ¹	LP ¹	—	—	—	—	12	31+
7.5-8.0	0	—	—	—	—	—	—	—	—	—	—	—	—	—
8.0-8.5	1	8.25	2.20	0.73	9.28	4.05	LP	LP	—	—	—	—	12	31+
8.5-9.0	0	—	—	—	—	—	—	—	—	—	—	—	—	—
9.0-9.5	1	9.07	2.44	0.78	7.39	4.69	LP	LP	—	—	—	—	—	—
9.5-10.0	0	—	—	—	—	—	—	—	—	—	—	—	—	—
10.0-10.5	1	10.18	3.02	0.88	—	5.25	LP	LP	—	—	—	—	—	—
10.5-11.0	2	10.88	3.33	0.98	7.67	5.26	16	LP	3	25	21	14	—	—
11.0-11.5	0	—	—	—	—	—	—	—	—	—	—	—	—	—
11.5-12.0	1	11.58	3.48	0.88	—	5.72	16	LP	3	25	21	14	—	—
12.0-12.5	3	12.38	3.98	1.08	7.20	5.56	17	2	3	25	21	14	—	—
12.5-13.0	5	12.62	4.13	1.10	—	5.67	—	2	3	26	22	—	—	—
13.0-13.5	3	13.20	4.27	1.16	—	6.35	—	2	3	25	22	15	—	—
13.5-14.0	1	13.67	4.19	1.21	5.30	6.98	18	2	3	26	22	15	—	—
14.0-14.5	3	14.32	4.74	1.16	—	7.03	—	—	—	—	—	—	—	—
14.5-15.0	4	14.72	4.69	1.28	—	7.21	—	—	—	—	—	15	—	—
15.0-15.5	4	15.30	5.03	1.38	4.57	7.78	17	2	3	26	22	14	—	—
15.5-16.0	3	15.78	5.00	1.34	3.96	7.83	—	—	—	—	—	—	—	—
16.0-16.5	4	16.28	4.87	1.26	3.54	7.70	—	2	3	26	22	16	—	—
16.5-17.0	2	16.85	5.12	1.21	4.14	8.09	—	—	—	—	—	—	—	—
17.0-17.5	2	17.07	5.05	1.32	4.14	8.10	19	2	3	26	21	16 ²	—	—
17.5-18.0	3	17.64	5.67	1.58	5.20	8.35	19	2	3	26	22	16	—	—
18.0-18.5	5	18.17	5.74	1.46	4.71	8.68	19	2	3	26	22	16	—	—
18.5-19.0	2	18.71	5.71	—	5.07	9.12	19	3 ²	3	26	22	16 (18) ²	—	—

¹ LP—larval pectoral and larval pelvic in respective columns.

² Counts made after dissection include both branched and unbranched rays for the total number.

that at between 15 and 18 mm the young toadfish, possessing the external adult features, becomes a free-swimmer and the appearance differs from the adults in magnitude only.

MERISTIC AND MORPHOMETRIC CHANGES

Table 1 summarizes the important meristic counts and body measurements in rela-

tion to ontogenetic development. Fig. 13A indicates that the head grew at a constant rate in relation to the total length during the early development, increasing in the present study 0.34 mm in length for every millimeter of increase in total length. Fig. 13B indicates that the anus was roughly one-half the distance of the body and remained in that relationship throughout the larval and young stages. The distance from snout to anus increased 0.48 mm per millimeter of total length.

Greatest body depth, however, decreased 0.62 mm (see Fig. 13C) with every millimeter of growth during early development (before 16.6 mm total length), then increased 0.73 mm per millimeter of total length during the latter part of the prolarval period (after 16.6 mm total length). This pattern resulted from the absorption of the gigantic yolk sac.

Fin delineation was well marked at 13.7 mm in length (Fig. 7): the counts as they were observed are given in Table 1.

Myotome counts were attempted but became impossible after the first two observations. The counts present may not be complete since Tracy (1959:32) stated that such counts are almost impossible as early as the maturation of the 31st somite in development. Jordan and Evermann (1898:2315) gave the vertebrae count for this genus as $12 + 22$; pre-caudal and caudal vertebrae, respectively. Dissection of six adult fish disclosed $11 + 23$ vertebrae. Dr. W. R. Taylor corroborated the latter counts with skeletal material of *Opsanus tau* at the U. S. National Museum.

Fin ray counts observed here are in agreement with those of Schultz and Reid (1937: 212) who gave the following fin ray count ranges for adults: Pectoral 19-21, anal 21-22, dorsal spines II or III, and dorsal soft rays 24-26. Observations on 10 adult fish showed an average of 16 caudal rays. On dissecting these a total of 18 rays, 12 branched and 6 unbranched (3 dorsally and 3 ventrally), were found in almost every case.

The full complement of various fin rays was attained at these sizes (Table 1): pectoral—17.1 mm T.L.; spinous dorsal apparently—10.8 mm; soft dorsal—12.8 mm;

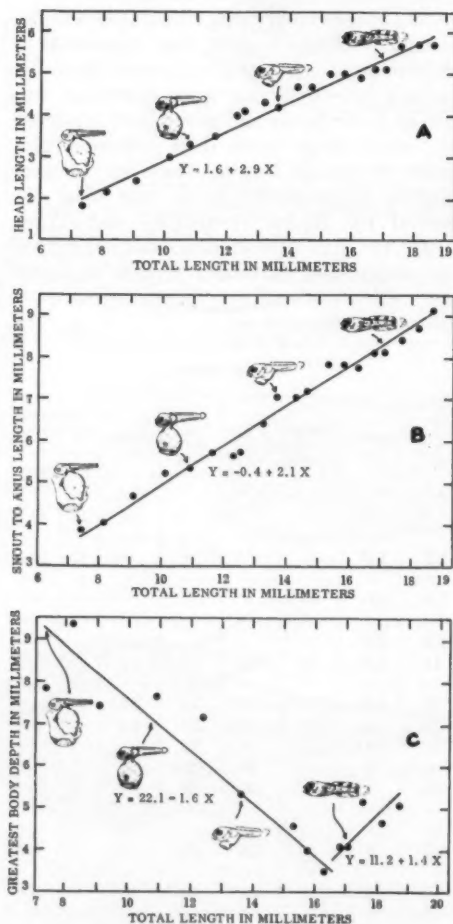


Fig. 13.—Regression of: (A) head length, (B) snout to anus length, and (C) greatest body depth, on total length of the oyster toadfish. Dots for (A) (B) and (C) represent both single measurements and the averages for a group of measurements. The regression line is fitted by the method of least squares. The outline drawings of larval and juvenile stages are not drawn to scale.

anal—12.8 mm; caudal—probably about 18.0 mm.

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Notes and Comments

Some Observations on Rearing Blue Crab Larvae¹

ABSTRACT

Foods tested were found inadequate for rearing the zoeae of the blue crab, *Callinectes sapidus*. Microorganisms associated with these foods increased larval mortality. This was controlled to some extent by addition of Terramycin HCl to rearing bowls. Large differences in survival were found between zoeae from different parents hatched and reared under identical conditions.

Blue crabs, *Callinectes sapidus*, were successfully reared from larvae to the adult form by Costlow, et al. (1959:222-3) and by Costlow and Bookout (1959:373-96). Survival, however, was low, ranging from 1 to 8 percent. Studies to determine the effects of environmental factors on larval survival require an abundant supply of healthy, active zoeae for detailed experiments. Since an adequate food for early zoeal stages is a major requirement for increased survival, a number of organisms and organic materials were tested. Those with no apparent utilization as food included cultures of 11 genera of phytoplankton (*Gymnodinium*, *Amphidinium*, *Chlamydomonas*, *Platymonas*, *Isochrysis*, *Monochrysis*, *Prorocentrum*, *Nitzschia*, *Carteria*, *Chlorella*, and *Dunaliella*), animal tissues (beef, beef liver, shrimp, clam, and mussel), and eggs from several unidentified species of fish and barnacles. Two foods, *Arbacia punctulata* eggs and *Artemia salina* nauplii, used by Costlow and his co-workers were tested separately and in combination. Repeated experiments with larvae in the first three zoeal stages demonstrated feeding on *Arbacia* eggs, but not on *Artemia* nauplii.

Microorganisms (protozoans, fungi, and bacteria) associated with the foods used in the above experiments adhered to and often weighted down or entangled the zoeae. Two dyes, having fungicidal properties, and four antibiotics were tested in an effort to eliminate these organisms and increase zoeal survival. The dyes, malachite green and Victoria blue R, were toxic to the zoeae at low concentrations. Chloromycetin, in the dose range of 25 to 100 mg/l, produced a slight increase in zoeal survival for the first three days, but an adverse effect by the end of seven days. No effect was observed with Penicillin G in concentrations of 50,000 to 200,000 units/l. A difference in survival

was observed when Terramycin HCl was used. At concentrations of 15, 30, 45, and 60 mg/l, survival was 76, 71, 83, and 58 percent, respectively, at four days as opposed to 55 percent for the controls, and on the fourteenth day was 16, 20, 23, and 18 percent, respectively, as opposed to 3 percent for the untreated control group. Preliminary experiments with Aureomycin produced results similar to those obtained with Terramycin. In all studies, greatest mortality occurred at the time of molting.

During the feeding experiments, it was found that considerable variation in survival occurred between zoeae from different parents. To further observe these differences, egg masses from two groups of five crabs each were hatched and reared under identical experimental conditions. All zoeae were fed on a combination diet of *Arbacia* eggs and *Artemia* nauplii and were kept at a temperature of 24°C. and a salinity of 25‰. Curves representing

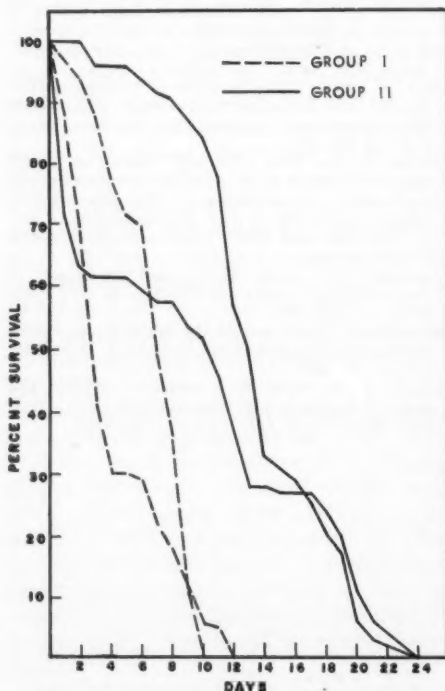


Fig. 1.—Extremes of survival for zoeae of the blue crab, *Callinectes sapidus*, from two experimental groups.

¹ Studies performed by the Oyster Institute of North America under contract to the U. S. Bureau of Commercial Fisheries, Fish and Wildlife Service.

extremes of survival for zoeae from each group are shown in Fig. 1. For Group I zoeae (broken lines), total survival varied from 30 to 78 percent by the fourth day. All were dead in 12 days and no molting occurred. Some Group II zoeae (solid lines), tested under similar conditions, survived 24 days. Greatest survival difference, about 34 percent, occurred at approximately six days. A large number of second stage zoeae (321 or 47 percent) began to appear on the seventh day, and 5 third stage zoeae appeared, starting on the eleventh day. The reason for these differences in survival is unknown.

These preliminary studies indicate that although zoeal survival may be enhanced by the addition of certain antibiotics to rearing bowls, the lack of a completely adequate, readily avail-

able food source points out the need for additional studies on this phase of investigation.

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Comments on the Abundance and Ecology of the Ascidian *Amaroucium constellatum* in Sinepuxent and Chincoteague Bays¹

ABSTRACT

The ascidian *Amaroucium constellatum* inhabits the shallow coastal Sinepuxent and Chincoteague Bays and was found predominantly over mud, mud-oyster, oyster bottoms or on pilings and occasionally on the oyster drill, *Urosalpinx cinerea*, where moderate currents and salinities above 28 ppt prevail. *A. constellatum* was also noted on sand bottoms to a depth of five fathoms in coastal waters near Chincoteague, Virginia.

Van Name (1945:38-40) and Miner (1950:848) stated that the ascidian *Amaroucium constellatum* Verrill occurs from Cape Cod to the Gulf Coast of Florida in one to 15 fathoms of water where it is most common on rocks (Costello, et al. 1957:202) and wharf pilings. Cowles (1930:366-7) in his study of Chesapeake Bay and its offshore waters did not record this species in the Maryland-Virginia area. Scott (1934:1-53; 1945:126-38; 1946:66-80; 1952:226-47) has contributed greatly to the knowledge of the embryology and early development of this species. Data on the abundance, habitat requirements and occurrence of *A. constellatum* in seashore bays are lacking in the literature.

While conducting a monthly trawl survey in 1959, *A. constellatum* was found throughout Sinepuxent and Chincoteague Bays in Maryland and Virginia (Fig. 1), except for the Public Landing and Fox Hill Levels sample areas. Its absence in those areas could possibly be the result of the weak water currents or low salinities that persist there. Colonies 60 mm in diameter and 30 to 40 mm high were collected. Their texture and color agreed with that given by Van Name (1945:39),

"Surface of colony is smooth and its texture gelatinous and only moderately firm. Test is opaque but the color of zooids renders them conspicuous. In life, color of test varies from cream color through various shades of yellow (or more frequently flesh-colored) to a pale orange or reddish." The cloacal chambers, however, did not contain the usual three to four bright purple tadpole shaped larvae (Verrill and Smith 1873:704). Numerous buds of developing zooids were found around the old colonies similar to that described by Berrill (1935:327-9). *A. constellatum* was found from April to December with the greatest number of colonies being collected between September and December. Greatest concentrations of this species occurred in December (Table 1) south of White Rock and in the area of Franklin City to Chincoteague, Virginia where the salinities were usually 28 ppt or more or near that of the adjacent ocean. In order to compare abundance between stations (each sample area was three-fourths of a mile long and 25 feet wide) a scale from 1-10 was devised. This scale was based on that portion of an ordinary 12 quart bucket that the sample occupied.

Wells (1957:124-6) characterizes the bottom of Sinepuxent Bay as mostly sand and mud. The western side of Chincoteague Bay, in general, has a mud or mud-oyster bottom while sand bottoms predominate on the eastern side of that bay. The latter are constantly shifted by the wave action that prevails in these readily wind-overturned shallow (average depth is six feet) bays. Perhaps it is this action that accounts for the absence or inability of this ascidian to remain attached to the sandy bottoms of the eastern portion of these bays. Evidence that partially bears out this premise stems from observations in the summer of 1957 when a small barrier fence was laid on the bottom near Mills Island. The fence was part of the copper barrier oyster drill control experiments of the U. S. Bureau of Commercial Fisheries. Great quantities

¹ Contribution No. 165, Maryland Department of Research and Education, Solomons, Maryland.

Fig. 1.—Areas inhabited by the ascidian *Amaroucium constellatum* in Sinepuxent and Chincoteague Bays.

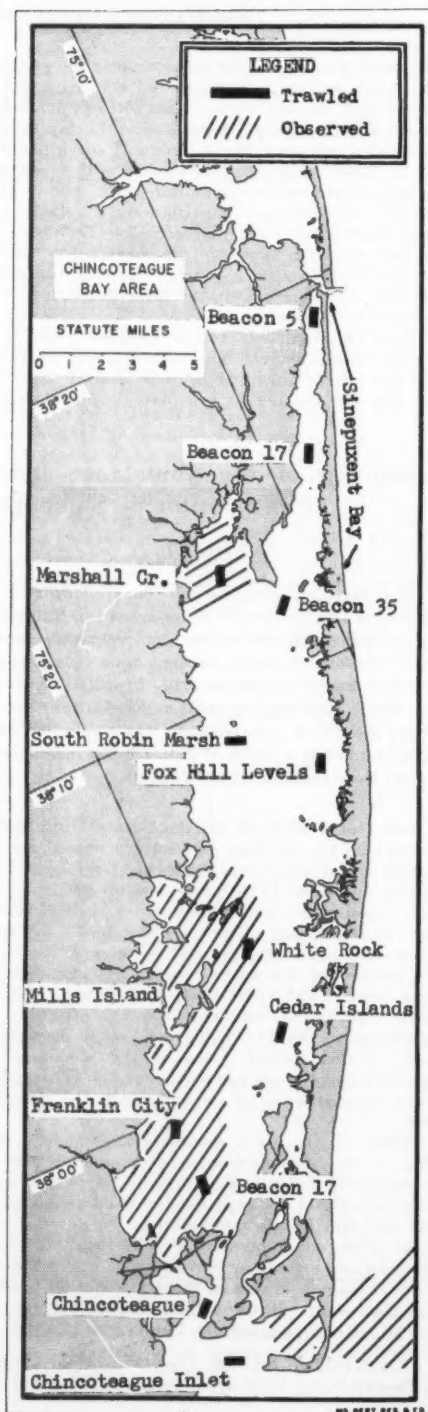


TABLE 1.—Monthly abundance of the ascidian *A. maroucium constellatum* at sample sites throughout Sinepuxent and Chincoteague Bays, 1959.

Locality	Month							
	April	May	June	July	August	Sept.	Oct.	Dec.
Beacon 5 Maryland	1	1	1	1	1	1	1	1
17 Maryland	1	1	1	2	2	1	1	2
35 Maryland	1	1	—	1	3	2	1	2
Marshall Cr.	—	—	—	—	2	2	1	1
South Robin Marsh	—	—	—	—	—	—	—	—
Fox Hill Levels	—	—	—	—	—	—	—	—
White Rock	1	1	1	1	3	4	3	3
Cedar Islands	1	1	1	5	3	2	1	1
Franklin City	3	3	4	5	6	7	9	10
Beacon 17 Virginia	3	3	5	5	5	6	8	10
Chincoteague City	—	—	—	1	1	1	1	1
Chincoteague Inlet	—	—	—	—	—	—	—	1

of these ascidians, 30-60 mm in diameter, had drifted against this fence each week, apparently after having broken away from previous attachments. Thus, in Sinepuxent and Chincoteague Bays *A. constellatum* is found on mud, mud-oyster or oyster bottoms, contrary to that noted for most species of *Amaroucium* (Van Name 1945:1-38). However, when found on a mud bottom *constellatum* is almost always found attached to oysters, shells, or some other hard object. Occasional small colonies are often found attached to the oyster drill, *Urosalpinx cinerea* (Say). Likewise *A. constellatum* was commonly found attached to oyster stakes (poles used to mark the boundaries of leased oyster grounds) south of White Rock. *A. constellatum* is also known in the coastal waters off Chincoteague, Virginia (Fig. 1) over sand bottoms to a depth of five fathoms.

Although *A. constellatum* has been found elsewhere, together with the similar ranging *A. pellucidum* (Van Name 1945:40), which Grave (1921:1-4; 1922:27-33) has shown to be distinct, the latter species was not discovered. *A. pellucidum* is a deeply cleft, sand encrusted-embedded form whose stomach is bright red. Likewise *pellucidum* seems to prefer sandy bottoms and swift tidal currents (Grave 1921:38). Perhaps it will be found in the inlets near Ocean City, Maryland or Chincoteague, Virginia, which areas would fulfill the ecological requirements of this species. Of the 22 recognized species of *Amaroucium* (Van Name 1945:21) the only other synoicid ascidian that could possibly be present in these waters is the smooth, whitish, platelike (one to two inches long, six inches high and one inch thick) *A. stellatum*. If *stellatum* is present in these waters it might also be found with *A. pellucidum* over sandy bottoms with extremely swift currents.

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Homing Tendency of American Shad, *Alosa sapidissima*, in the York River, Virginia

ABSTRACT

To determine the homing tendency of American shad in the York River, Virginia, 313 fish were tagged on the spawning ground in the spring of 1959. During the following spring, 14 marked fish were recaptured within the York River system and 5 in the vicinity of tagging. None was recaptured on the spawning ground of any other river, suggesting that shad having spawned once in this river system would return to spawn again.

Successful management of the Chesapeake Bay shad fishery is largely dependent on whether or not fish return to their native stream to spawn. In the fall of 1950, E. A. Hollis and C. M. Coker released 737 marked fingerlings near the mouth of Mill Creek which empties into the Patuxent River near Solomons, Maryland, in an experiment conducted by the U. S. Fish and Wildlife Service and the Chesapeake Biological Laboratory. In 4 to 6 years after tagging, three tags were returned from Chesapeake Bay where the tagged fish could have been on their way to the Patuxent, and two were returned from the Solomons Island area. None was recovered from an area which indicated that the fish might have spawned in any place but its parent stream (Talbot and Sykes, 1958:486). Based on 19 years tagging data, Talbot and Sykes *op. cit.*:488) demonstrated that shad from Chesapeake Bay return to their home streams to spawn.

During the spring of 1959, the U. S. Bureau of Commercial Fisheries conducted a tagging program on the York River to determine if adult shad having spawned once in this river will return to spawn again.

The York River, formed by the junction of the Mattaponi and Pamunkey Rivers, flows southeasterly about 30 miles, and empties into Chesapeake Bay at Tue Point. Shad for tagging were captured by drift gillnets on the spawning grounds in the above tributaries, approximately 15 miles upstream from their mouths. Fish were marked with Petersen disk tags identified by number, return address, and reward notice. From May 4 through 14, 99 fish were tagged in the Mattaponi, and 214 were tagged in the Pamunkey. To recover tags, fishermen were canvassed during the remainder of the 1959 shad fishing season, and also during the 1960 season. Receipt of tags from other areas depended upon mail returns.

Twenty-seven of the fish marked in the Mattaponi and 24 of those marked in the Pamunkey were recaptured within the river system during the spring of tagging. It was assumed, therefore, that 72 marked fish from the Mattaponi and 190 marked fish from the Pamunkey spawned and returned to the ocean. In the spring following tagging, 2 marked fish from the Mattaponi and 12 marked fish from the Pamunkey were recaptured within the York River system; 5 on the shad spawning grounds of the Pamunkey and Mattaponi where the fish had been tagged the previous

TABLE 1.—Recaptures of adult American shad, *Alosa sapidissima*, tagged in the York River system, Virginia, 1959.

Tagging Site	Number Tagged	Recoveries			
		Number	Gear (net)	Date	Area
Mattaponi River	99	18	Drift gill	May 4-20, 1959	Vicinity of tagging
		8	Stake gill	May 8-22, 1959	York River
		1	Pound	May 14, 1959	York River
		1	Pound	May 2, 1960	Chesapeake Bay
		2	Drift gill	April 10-21, 1960	Vicinity of tagging
Total	99	30			
Pamunkey River	214	11	Drift gill	May 6-22, 1959	Vicinity of tagging
		12	Stake gill	May 9-19, 1959	York River
		1	Pound	May 14, 1959	Chesapeake Bay
		1	Otter trawl	May 7, 1960	Narragansett Bay
		1	Pound	April 2, 1960	Pamlico Sound
		1	Pound	May 10, 1960	Chesapeake Bay
		8	Stake gill	April 4-27, 1960	York River
		3	Drift gill	April 10-May 9, 1960	Vicinity of tagging
		1	Drift gill	April 21, 1960	Mattaponi River
Total	214	39			

year, and 9 downstream from the tagging site. Four tagged fish were recaptured in other areas: 2 in Chesapeake Bay, 1 in Pamlico Sound, and 1 in Narragansett Bay. Recaptures of marked fish are shown in Table 1.

One shad tagged on the spawning ground in the Pamunkey was recaptured on the spawning ground in the Mattaponi the following spring. Hammer (1942:34-5) made a study of scales and body measurements of adult shad taken in the Chesapeake Bay area and suggested the existence of at least two populations within the York system. Unpublished data based on studies conducted by the author on juvenile shad collected over a 3-year period from each tributary, showed no significant differences between scute, pectoral, anal, and dorsal fin ray counts. The five tagged fish recaptured on the spawning grounds the following year indicated that most shad return to their home tributary, but the meristic studies and the one tag return suggested some intermingling probably occurred on the spawning grounds.

The wide geographical distribution of tags returned from outside the river system the season after tagging was not surprising since Talbot and Sykes (*op. cit.*:482) found that shad tagged on the spawning grounds in the Hudson and Connecticut Rivers were recaptured in the spring of the following year from North Carolina to Long Island. They found as the time of spawning approached, that the recaptures were made nearer the mouth of the

river where the fish had been tagged and to which they were apparently returning. In the present study, the marked fish recaptured outside the river could conceivably have been en route to their parent stream to complete the spawning cycle or may have completed the cycle before being recaptured. None was recaptured on the spawning ground in any other river, which suggested that shad having spawned once in the York River system would return to this system to spawn again. The results of this and other studies suggested that York River shad possess a strong homing tendency.

Mr. William H. Massmann, Virginia Fisheries Laboratory, helped with the tagging program, and his assistance is gratefully acknowledged.

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Recent Records of the Xanthid Crab, *Panopeus herbsti*, from Maryland and Virginia Waters¹

ABSTRACT

Fifty-one recent (1956-1960) specimens now firmly establish the xanthid crab, *Panopeus herbsti*, as part of Maryland and Virginia's mud crab fauna. Nine specimens of this mud crab were taken in Chesapeake Bay as far north as the Patuxent River while 42 were recorded for Chincoteague Bay. Some specimens from Chesapeake Bay were larger and found in shallower water than previously reported. The salinity range for this species has been extended from 14-19 ppt. to 10-34 ppt.

Panopeus herbsti (Milne-Edwards) is the largest of five species of xanthid crabs reported by Ryan (1956:138-62) after a survey of 189 stations throughout Chesapeake Bay. The only previous record of its occurrence in Chesapeake Bay is given by Rathbun (1930:338) who reported two males and one ovigerous female collected by the

Steamer *Fish Hawk* from the Magothy River in 1916. No other specimens have been reported from the Maryland part of Chesapeake Bay (Cowles, 1930:355-6) or from Chincoteague Bay. Blake (1953:29) has recorded fossil *P. herbsti* from Wailes Bluff, St. Mary's County, in Pleistocene deposits near Cornfield Harbor a few miles above the Potomac River mouth. This note brings together all the available recent records and firmly establishes its occurrence in this region.

Fifty-one specimens of *P. herbsti* have been collected between 1956 and 1960 from Chesapeake and Chincoteague Bays (Fig. 1). Forty-two were collected in Chincoteague Bay, of which sex data for 17 (14 males, 3 females) are available. Nine specimens were taken in Chesapeake Bay's Tangier Sound (1 male, 1 female), Patuxent River (2 males), and Potomac River tributaries of Breton Bay (1 male) and St. Mary's River (3 males, 1 female). Of those captured in Chincoteague Bay, 38 were captured by setting 150 traps on three occasions (September, 1956, and June and August, 1957). These were set in five lines across the bay as part of another study.

Data for 26 specimens are given in Table 1.

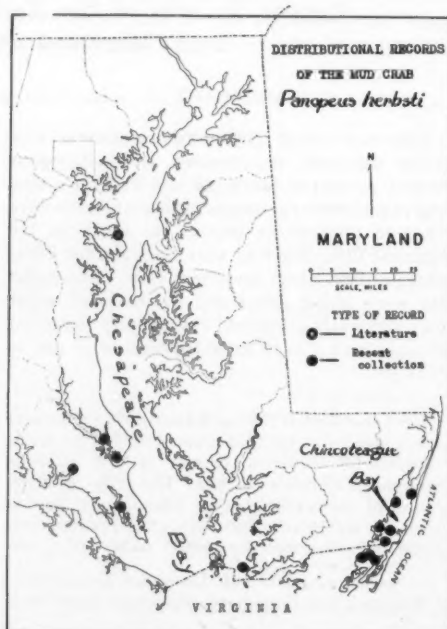
¹ Contribution No. 164, Maryland Department of Research and Education, Solomons Maryland.

TABLE 1.—Location, dates, sex, size, depth, and salinities where the xanthid crab, *Panopeus herbsti*, was found in Chesapeake and Chincoteague Bays.¹

Bay	Date	County	Location	Sex	Maximum Carapace Width (in mm)	Depth	Salinity
Chesapeake	Sept. 15, 1958	St. Mary's	Breton Bay, Leonardtown	Male	32.1	3	10.9
	Sept. 15, 1958	Calvert	St. Leonard's Creek, 400 feet from mouth	Male	37.9	6	15.4
	March 24, 1959	Calvert	Chesapeake Biological Laboratory pier, Solomons	Male	43.7	8	13.9
	October 28, 1959	Somerset	Great Rock, Tangier Sound	Male	30.5	6	20.9
				Female	32.3	6	20.9
	Sept. 21, 1960	St. Mary's	Seminary Pier, St. Mary's City	Male	29.7	6	10.1
				Male	31.1	6	10.1
				Female	31.2	6	10.1
	Oct. 18, 1960			Male	32.4	6	14.4
	June 18, 1957	Worcester	Line 3, Rattlesnake Landing to Green Run Bay (Middle Station)	Male	12.9	5	28.0
Chincoteague			Line 4 George Island Landing to Cedar Islands (Middle Station)	Male	12.9	7	29.3
				Female	28.3	7	29.3
				Female	28.3	7	29.3
			Line 5, Cockle Pt. to Wildcat Pt. (East Station)	Male	6.3	5	30.9
				Male	8.5	5	30.9
				Male	12.9	5	30.9
	August 28, 1957		Line 1, Marshall Creek to Tingle Island (East Station)	Male	22.7	4	32.4
			Line 4 (see above)	Male	26.0	7	34.0
			Line 5 see above (West Station)	Female	32.8	7	34.0
				Male	13.9	7	33.2
				Male	17.9	7	33.2
			Line 5 see above (Middle Station)	Male	16.0	6	33.9
	May 28, 1958		Rattlesnake Landing	Male	35.6	3	19.7
	July 17, 1958			Male	38.7	3	31.6
				Male	40.5	3	31.6
	June 3, 1959		Public Landing	Female	26.5	2	28.4

¹ Detailed data for the 25 specimens (20.9–31.8 mm carapace width) taken in Chincoteague Bay in September, 1956, are not given here.

Fig. 1.—Locality records for the mud crab, *Panopeus herbsti*, from Chesapeake and Chincoteague Bays.



Chesapeake Bay specimens ranged from 29.7–43.7 mm in maximum carapace width, of which the latter is 6.4 mm larger than that noted by Ryan (1956:149), yet far smaller than that (62 mm) cited by Fowler (1941:406). Likewise, the females from St. Mary's River and Great Rock in Tangier Sound are larger than those examined by Ryan. The carapace size range of Chincoteague Bay specimens listed in Table 1 (6.3–40.5 mm) and those taken (but not listed) in September, 1956 (20.9–31.8 mm) are typical for the species.

The specimens described herein were taken in a mud-oyster habitat and salinities above 14 ppt, environmental conditions which agreed with similar observations cited by Ryan (1956:149). Recorded depths ranging from 2–6 feet were much shallower than previously reported by Ryan. The 34.0 ppt salinity of the middle station of Line 4, Chincoteague Bay, was much higher than the reported 14–19 ppt range for *P. herbsti* noted by Shuster (1959:45) in Delaware Bay or by Ryan. Salinities from Breton Bay and St. Mary's River (Table 1) were lower than the range given by Shuster. Although McDermott and Flower (1952:48) found ovigerous female *P. herbsti* in June in Delaware Bay and Lunz (1937:13) found them in May in the Carolinas, the females reported herein for June were not ovigerous. The data for 25 specimens taken in Chincoteague Bay in September, 1956 was received after this article was written. They are not plotted on Fig. 1, but were captured

by traps at the same locations as others for Chincoteague Bay.

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Another Rainbow Snake, *Abastor erythrogrammus*, from Maryland

ABSTRACT

A fourth authentic Maryland specimen of the fossorial rainbow snake is reported from near Newburg, Charles County. An adult female 930 mm long, it is the only complete specimen now in collections from Maryland. Biological data for the specimen and the ecological aspects of this species in Maryland are discussed.

An adult female rainbow snake, *Abastor erythrogrammus* (Latreille), was found DOR (dead on road) in near-perfect condition on the sandy east shoulder of U. S. 301 approximately 1.4 miles NE of the Potomac River Bridge, near Newburg, Charles County, Maryland, by Joseph Kilmon and Ray Merson, on July 10, 1960, ca. 7:30 PM (DST). This interesting find occurred exactly 23 years to the month after the first and only specimens known to have been taken in Maryland were found (McCauley, 1939:54). Muscle contractions and uncoagulated blood coming from the mouth indicated that the snake had been killed shortly before it was found, apparently moving across the heavily-traveled highway at dusk. Dissection revealed

the sex and the fact that the snake had been struck at mid-body, where the vertebrae and ribs were shattered and part of the elongate liver had been destroyed. There were no recognizable food materials in the stomach or intestine. No eggs were found, although in the more northern part of its range *Abastor* apparently performs oviposition in early July (Richmond, 1945:30).

The snake, No. R3012 in the herpetological collection of the Natural History Society of Maryland, measures 930 mm total length, of which 123 mm (13.2%) comprises the tail. It has 174 ventrals and 38 caudals (sum 212) including the horny end scale, 6 upper labials, 8 lower labials, scale rows 19–19–19, and a divided anal plate. Head scutellation is normal for the species and the cephalic plates are marked with red. The chin and upper labials are light (probably yellow in life), and lower labials 1 through 5 and the chin shields are spotted with black. The lateral red stripes are at the level of the 6th scale row, barely encroaching on the 7th. The mid-dorsal red stripe is made up of roughly arrow-shaped markings on each scale of row 10. It is continuous from the parietals to the level of the 6th caudal (from the anus). Scale rows 1 and 2 are pink-red, and the lower half (diag-

nally) of the 3rd row is light pink. Near the head, at the level of the 5th ventral scute, the 3rd row of scales and part of the 4th is light in color. There is a row of large black spots at the edge of each side of the ventrals, and a mid-ventral row of black spots running from the 29th ventral scute (counting from the head) to the 4th. The rest of the venter is pink.

The original Maryland specimens were taken on the Stump Neck peninsula, Charles County, in July, 1937 by Civilian Conservation Corps workers building a road. One was accidentally dug from sandy soil; the other two were found under stumps. That this species is markedly fossorial is well known. Thus Cope (in Wright and Wright, 1957:84) reported specimens from the Pamunkey River, Virginia, dug from a clay bank under ten feet of sand, and Florida specimens dug from nearly equal depths in sand. Richmond (1945) found that the majority of specimens taken in Virginia were plowed from the ground. Only the skin of one of the Maryland specimens, headless and tanned, was retained. It apparently resided in the possession of Mr. Howard Hassler of Washington, D. C. as late as 1945 (McCauley, 1945:57). I have not attempted to trace this skin, but McCauley (1939, *loc. cit.*) gave the following description: ventrals 162, caudals 36, total length 995 mm (headless), tail 175 mm, scale rows 17-19-17. The sexual dimorphism data presented by Richmond (1954, *loc. cit.*) indicate that this specimen was a female. One of the other Stump Neck specimens was a female containing an undetermined number of eggs, and the specimen was probably taken early in the month of July. The locality from which the current specimen was taken lies on a peninsula approximately 2.5-3 miles wide between the Potomac River and the headwaters of the Wicomico River. Tributary streams from Allens Fresh Run to the east and Clifton Creek to the west enter the immediate area where the snake was found.

In Maryland *Abastor* is second in rarity only to the northern pine snake, *Pituophis melanoleucus melanoleucus* (Daudin), which, indeed, may not be a legitimate member of the local herpetofauna. It had long been looked upon by many local workers as another of those forms which, like *Pituophis*, *Siren lacertina*, and *Hyla femoralis*, would probably never be seen again in this state. However, it is likely that *Abastor* is actually more abundant in Maryland than the paucity of known occurrences would indicate. Throughout the main part of its range this secretive snake is principally nocturnal and crepuscular and is consequently fairly difficult to find. Only more exhaustive investigation in the Potomac lowlands of Charles and possibly St. Mary's Counties could unearth further Maryland specimens.

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Measurements and the Occurrence of Young Sandbar Shark, *Carcharhinus milberti*, in Chesapeake Bay, Maryland¹

ABSTRACT

Measurements of five young specimens of the sandbar shark *Carcharhinus milberti*, 613-747 mm in length, captured in Maryland's Chesapeake Bay in 1958-1959 are presented. Variation in fin sizes, body proportions and growth are compared with detailed literature records. These young specimens were shorter and stouter than known. Adult *C. milberti*, although reported sighted, have yet to be captured in the upper Chesapeake Bay, al-

though the capture of these specimens indicates the bay is a spawning area.

Measurements illustrating variation in young or newly born specimens of the sandbar or brown shark, *Carcharhinus milberti* (Müller and Henle) [= *Eulamia milberti*, Springer 1950:8; 1960A:2], are absent in the literature. Uhler and Lugger (1876:162) first reported the species as "common on the coast of Maryland's Worcester County and the drains emptying into the ocean." Truitt, et al. (1929:29) cited that this species had been recorded in Cecil, Charles, Prince Georges [in Chesapeake Bay], and Worcester Counties; however, they did

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TABLE 1.—Dimensions and proportions in percent of total length for five sandbar sharks, *Carcharhinus milberti*, from Chesapeake Bay, Maryland compared with that of Bigelow and Schroeder (1948: 370).

Item	B & S USNM 104969	Flag Pond, Calvert County USNM 195831 July 21, 1958								West River Anne Arundel County July 27, 1959	
		Male		Male		Male		Female		Male	
		Percent	Measure- ment (in mm)	Percent	Measure- ment (in mm)	Percent	Measure- ment (in mm)	Percent	Measure- ment (in mm)	Percent	Measure- ment (in mm)
Trunk at origin pectoral											
a) breadth	12.0	86.0	13.5	79.0	13.7	79.0	14.0	86.0	14.0	84.0	11.4
b) height	12.9	92.0	14.5	86.0	15.0	81.0	14.4	92.0	15.0	97.0	13.1
Snout in front of outer											
a) nostrils	4.1	25.0	3.9	32.0	5.6	32.0	5.7	32.0	5.2	30.0	4.1
b) mouth	8.2	51.0	8.0	51.0	8.9	49.0	8.7	49.0	8.0	60.0	8.1
Eye: Horizontal diameter	2.1	11.0	1.7	10.0	1.7	8.0	1.4	10.0	1.6	20.0	2.7
Mouth											
a) breadth	9.5	60.0	9.4	54.0	9.4	51.0	9.1	62.0	10.1	65.0	8.8
b) height	4.7	29.0	4.6	32.0	5.6	25.0	4.4	22.0	3.6	30.0	4.1
Nostrils between inner ends	5.9	38.0	6.0	38.0	6.6	34.0	6.0	38.0	6.2	45.0	6.1
Gill opening lengths											
a) 1st gill slit	3.0	19.0	3.0	16.0	2.8	16.0	2.8	19.0	3.1	20.0	2.7
b) 2nd gill slit	—	22.0	3.5	17.0	3.0	17.0	3.0	19.0	3.1	22.0	3.0
c) 3rd gill slit	—	21.0	3.3	19.0	3.4	19.0	3.4	21.0	3.4	22.0	3.0
d) 4th gill slit	—	19.0	3.0	19.0	3.4	19.0	3.4	17.0	2.8	14.0	1.9
e) 5th gill slit	2.5	17.0	2.7	13.0	3.0	17.0	3.0	14.0	2.3	14.0	1.9
Dorsal											
a) vertical height	10.9	60.0	9.4	51.0	8.9	56.0	10.0	60.0	9.8	80.0	10.8
b) base length	13.3	70.0	11.0	67.0	11.7	64.0	11.4	70.0	11.4	87.0	11.8
Second Dorsal											
a) vertical height	3.1	19.0	3.0	14.0	2.4	16.0	2.8	19.0	3.1	20.0	2.7
b) base length	6.0	25.0	7.0	44.0	7.7	41.0	7.3	29.0	4.7	33.0	4.5
Anal											
a) vertical height	3.5	29.0	4.6	24.0	4.2	25.0	4.4	29.0	4.7	30.0	4.1
b) base length	5.7	29.0	4.6	44.0	7.7	44.0	7.8	30.0	4.9	38.0	5.1
Caudal											
a) upper margin	26.7	171.0	26.9	152.0	26.4	132.0	23.5	159.0	25.9	164.0	22.2
b) lower anterior margin	12.0	62.0	9.8	57.0	9.9	54.0	9.6	57.0	9.3	70.0	9.5
Pectoral											
a) outer margin	18.1	105.0	16.5	95.0	16.5	92.0	16.4	98.0	16.0	122.0	16.5
b) inner margin	6.3	35.0	5.5	32.0	5.6	30.0	5.3	32.0	5.2	54.0	7.3
c) distal margin	14.4	89.0	14.0	75.0	13.0	73.0	13.0	76.0	12.4	109.0	14.3
Distance snout to											
a) dorsal	28.3	197.0	31.0	171.0	29.7	165.0	29.4	178.0	29.0	205.0	28.3
b) dorsal	60.3	418.0	65.8	368.0	64.0	359.0	63.9	391.0	63.8	447.0	60.4
c) upper caudal	73.3	487.0	76.7	432.0	75.1	423.0	75.3	459.0	74.9	536.0	72.4
d) pectoral	24.7	133.0	20.9	121.0	21.0	124.0	22.1	127.0	20.7	150.0	20.3
e) pelvic	49.1	325.0	51.2	284.0	49.4	573.0	48.6	305.0	49.8	355.0	48.0
f) anal	61.5	410.0	64.6	360.0	62.6	348.0	61.9	378.0	61.7	455.0	61.5
Interspace between											
a) 1st and 2nd dorsal	20.7	222.0	35.0	200.0	34.8	191.0	34.0	216.0	35.2	250.0	33.8
b) 2nd dorsal & caudal	7.4	71.0	11.2	67.0	11.7	64.0	11.4	70.0	11.4	80.0	10.8
c) anal and caudal	7.4	75.0	11.8	68.0	11.7	64.0	11.4	70.0	11.4	50.0	6.8
Distance origin to origin											
a) pectoral and pelvic	27.4	175.0	27.5	165.0	28.7	151.0	26.9	181.0	29.5	173.0	261.0
b) pelvic and anal	13.3	79.0	12.4	73.0	12.7	67.0	11.9	68.0	11.1	97.0	13.1
Total length.....	747	635		575		502		613		740	
Teeth.....		14-2-16		15-2-13		15-2-14		14-2-15		14-2-13	
		13-1-13		12-1-12		12-1-12		13-1-12		14-1-13	

1 Bigelow & Schroeder.

not present measurements of young or old specimens. Hildebrand and Schroeder (1928:48) gave some ratios which apparently were taken from six specimens 450-648 mm in length. Fowler (1906:62-3) cited some body ratios for a 603 (23- $\frac{3}{4}$ inch) mm specimen from New Jersey waters. Joseph and Yerger (1956:116) noted the capture of two specimens 87 and 90.5 cm, in Alligator Harbor, Florida, yet these may have been *C. springeri*, according to Springer (1960B). Bigelow and Schroeder (1948:370) listed one detailed series of measurements of a young 740 mm male *C. milberti*. Springer (1960A:9) cited pectoral fin length measurements in percent of total length for three young specimens from Massachusetts as well as similar measurements for three adults from Florida.

Bigelow and Schroeder (1948:374) and Springer (1960A:14) concluded from their data that *C. milberti* migrates north from its Carolina to Florida wintering grounds (December to March) to occupy northern latitudes during the summer months of June to mid-September to drop its young. No free-swimming young have been reported from southern Florida although some of the larger females taken there carry embryos (Bigelow and Schroeder 1948:373; Springer 1960A:24). Young are taken during June to August along Long Island while the adult catch is composed of females with embryos nearly ready for birth.

The capture in 1958 (4 specimens) and 1959 (1) of extremely small 613-747 mm specimens of *C. milberti* definitely indicates that Chesapeake Bay is also a spawning ground for this species, as has been long suspected. Since there is such a paucity of data on newly born or small specimens, data are presented in Table 1 to indicate body variations and proportions. These specimens are considered newly born as they ranged from 24 $\frac{1}{8}$ to 29 $\frac{3}{8}$ inches long, lengths near that reported for such young at New York (Bigelow and Schroeder 1948:372; Springer 1960A:23). Had they been year-old specimens, the former would have had to be nearer three feet long, as a yearly growth of about 10" is normal for this species (Bigelow and Schroeder 1948:372).

Newly born or young *C. milberti* from Chesapeake Bay (Table 1) seem to be shorter and stouter than noted by Bigelow and Schroeder (1948:370) or Fowler (1906:62-3). Apparently, with age, this species lengthens proportionately more than it grows breadthwise. Note the extremely small eyes in the specimens examined herein. The snouts are broad for the short heads at the lengths studied. The first dorsal fin base lengthens with growth. The second dorsal is squarer in outline when young than at the longer lengths. Young *C. milberti* seem to have their fins positioned further apart than larger or adult specimens. The former is also

evident in the space ratios for origin to origin of the various fins in these younger specimens (Bigelow and Schroeder 1948:370). The lower lobe of the caudal fin seems to enlarge greatly between young (Table 1) and large specimens (Bigelow and Schroeder 1948:370). The pectoral fin outer margins agreed with the largest percentage (16.2) cited by Springer (1960A:9).

The presence of young *C. milberti* in Maryland's Chesapeake Bay is quite interesting. However, the problem of the conspicuous absence of adults is unexplained. The only large adult shark that frequents the upper portion of Chesapeake Bay is *Carcharhinus leucas* (Schwartz 1959:251-2; 1960:68-71). Although huge sharks often assumed to be *C. milberti* are reported seen in offshore oceanic waters and at Drum Point in Chesapeake Bay, a large adult has yet to be taken.

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Restriction of Very Young Red Drum, *Sciaenops ocellata*, to Shallow Estuarine Waters of Chesapeake Bay During Late Autumn¹

ABSTRACT

Young-of-the-year red drum, ranging from 20-90 mm total length and one to several months old, were found to be restricted to a shoal estuarine habitat in Chesapeake Bay during autumn months. Extensive trawl data from deep water during autumn and winter illustrate their absence from deep water throughout the bay. It is postulated that beginning in September planktonic *Sciaenops* are carried from the Atlantic ocean spawning area into Chesapeake Bay by the net upstream movements of deep sub-surface water currents of high density. After metamorphosis to a free-swimming stage, the young restrict their activities to shallow waters which may be important but temporary nursery areas. They may then rapidly descend to the ocean in early winter. Evidence is presented to show that the spawning may begin in August off the mid-Atlantic, a month earlier than was formerly believed.

This note presents some new data on the restriction of very young red drum, or channel bass, *Sciaenops ocellata* (Linnaeus), to shallow estuarine waters during late autumn months, in contrast to deeper waters where certain other sciaenids that enter Chesapeake Bay from the ocean are found. It also reevaluates the data on the beginning of spawning for this species in the mid-Atlantic region. Hildebrand and Schroeder (1928:278) remarked that little was known about the distribution and ecological requirements of young red drum, the adults of which reach a length of five feet, in the Chesapeake Bay region. Although the various investigators quoted below have somewhat extended our knowledge of this species, many aspects of the early biology are still unknown.

The best evidence, largely indirect, indicates that *Sciaenops* spawns in the Atlantic Ocean off the mid- and south-Atlantic states during the fall months. Although Hildebrand and Schroeder (*op. cit.*) and Pearson (1929:144) have implied that *Sciaenops* spawns in Chesapeake Bay, clear-cut evidence is unavailable. Adult fish in ripe-spawning condition have never been observed in the bay. Some of the young enter Chesapeake Bay shortly after the beginning of spawning and use the estuary as a nursery region, as do many other sciaenids. There is no data to show how the eggs and/or larvae are transported into the bay. It is possible to speculate that they are carried pas-

sively into the Chesapeake with the plankton by deep sub-surface water currents of high density with a net upstream movement (Pritchard, 1951:375), and are involuntarily carried far upstream before swimming actively (Wallace, 1936:480; Massmann, et al., 1954:22; Haven, 1957:96; Massmann, et al., 1958:364; and Massmann and Pacheco, 1960:154). In order to account for the occurrence of very small red drum far up the Chesapeake, it must be assumed, therefore, that planktonic *Sciaenops* are restricted to deep water like other species. After becoming free-swimmers, following metamorphosis at about 5 mm (see Pearson, 1929:140), however, they restrict their fall activities to shoal water.

Observations collected over a period of years (Table 1) indicate that young-of-the-year red drum, from one to several months old, make their appearance in Maryland estuarine habitat beginning in mid-September and are subsequently taken through all the fall months. Small *Sciaenops* have never been taken in Chesapeake Bay during winter months (December to February) when most other young and adult resident and immigrant species are found in deep water. There is a possibility that young *Sciaenops* descend rapidly to the ocean in early winter after their sojourn on the temporary shoal nursery areas. Newly hatched Atlantic croaker, *Micropogon undulatus*, an example of immigrant young entering the bay at about the same time as *Sciaenops*, have been regularly trawled in deep waters in many parts of the Chesapeake during late fall and winter months. Yet, Haven (1957:96) pointed out that *Micropogon* is never observed or captured near shore. All collections of young-of-the-year *Sciaenops* were made with beach seines in shallow water, rarely exceeding five feet in depth and in salinities ranging from 14-22‰. While no effort was made to collect this species simultaneously with a fine-meshed shrimp trawl when small *Sciaenops* were successfully taken with a beach seine, various data from limited trawl studies in Maryland by the Chesapeake Biological Laboratory and cooperative bay-wide trawl surveys with the Virginia Fisheries Laboratory (Mansueti, 1953:3) show an absence of the species in deep water.

Furthermore, Mr. William Massmann, of the ichthyology division of the Virginia Fisheries Laboratory, has trawled and seined extensively in fall and winter, sometimes simultaneously, in Virginia estuarine waters, and has informally remarked to me that young-of-the-year are lacking from trawl samples at all seasons. In fact, he regards the young-of-the-year as rather scarce in his collections, when the catches of all other gear were considered. This is in sharp contrast to the presence of the Atlantic croaker, spot, *Leiostomus xanthurus*, weakfish, *Cynoscion regalis*, all taxo-

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TABLE 1.—Size frequency distribution of young-of-the-year red drum, *Sciaenops ocellata*, seined from various localities in Chesapeake Bay during autumn.

Size Intervals in 5 mm Units (T.L.)	Months and Collecting Data ¹												Total	
	September			October								November		
	A	B	C	D	E	F	G	H	I	J	K	L		
20-25	1	—	1	—	—	1	—	—	—	—	—	—	3	
25-30	1	2	1	—	—	1	—	—	1	—	—	—	6	
30-35	4	1	—	1	—	5	—	3	6	—	—	3	23	
35-40	3	1	1	1	1	5	—	—	8	—	1	3	24	
40-54	—	1	1	2	—	15	—	—	5	1	1	5	31	
45-50	—	—	—	2	3	4	—	—	12	—	3	4	28	
50-55	1	—	—	—	—	9	—	—	2	—	6	3	21	
55-60	—	—	—	1	1	4	—	2	2	2	7	—	19	
60-65	—	—	—	—	—	1	—	—	3	—	—	1	5	
65-70	—	—	—	—	—	1	1	1	—	1	—	—	4	
70-75	—	—	—	—	—	1	—	—	1	1	1	—	4	
75-80	—	—	—	—	—	—	—	—	—	—	2	—	2	
80-85	—	—	—	—	—	—	—	—	—	—	1	—	1	
Total	10	5	4	7	5	47	1	6	40	5	22	19	171	

¹ A—Md., Patuxent River, Sandy Point, Solomons Island, 3 ft. water, salinity, 17‰, 30 ft. bag seine, 23 IX '54, RJM.

B—Md., Patuxent River, Drum Point, jct. Chesapeake Bay, 4 ft. water, salinity, 15‰, 30 ft. bag seine, 11 IX '55, RJM.

C—Md., Patuxent River, Sandy Point, Solomons Island, 3 ft. water, salinity, 16‰, 30 ft. bag seine, 23 IX '57, RJM.

D—Md., Patuxent River, Sandy Point, Solomons Island, depth and salinity unknown, small beach seine, 18 X '36, D. H. Wallace.

E—Md., Patuxent River, Town Point, depth and salinity unknown, small beach seine, 24 X '40, R. C. Hammer.

F—Va., Pocomoke Sound, at Saxis, 4 ft. water, salinity, 18‰, 30 ft. bag seine, 28 X '53, RJM.

G—Va., Chesapeake Bay, at Silver Beach, 3 ft. water, salinity, 22‰, 30 ft. bag seine, 30 X '53, RJM.

H—Va., Potomac River, at Lewissetta, 4 ft. water, salinity, 14‰, 30 ft. bag seine, 30 X '53, RJM.

I—Md., Patuxent River, Sandy Point, Solomons Island, 4 ft. water, salinity, 17‰, 30 ft. bag seine, 23 X '54, RJM.

J—Md., Patuxent River, Drum Point, jct. Chesapeake Bay, 4 ft. water, salinity, 16‰, 30 ft. bag seine, 23 X '57, RJM.

K—Md., Patuxent River, Sandy Point, Solomons Island, 4 ft. water, salinity, 15‰, 30 ft bag seine, 18 XI '53, RJM.

L—Md., Patuxent River, Sandy Point, Solomons Island, 3 ft water, salinity, 15‰, 50 ft. bag seine. 12 XI '60, RJM.

nomically and ecologically related to the red drum, in trawl samples from deep water in Maryland and Virginia. Gunter (1945:68) remarked pointedly that young-of-the-year *Sciaenops* in the Gulf of Mexico waters "are practically never taken in trawls." They are also apparently unavailable to plankton-collecting gear during late fall months when they are being carried from the ocean into lower Chesapeake Bay, since Pearson (1941:82) did not record *Sciaenops* among the many species of larvae encountered in tow-nets.

Welsh and Breder (1924:184) apparently were the first to provide data on the young in Chesapeake Bay. Six of the smallest examples available to them came from the bay. These fish measured 40, 42, 50, 51, 58 and 63 mm long, from which they illustrated the 42-mm fish in their Fig. 42. They

gave no date for these fish, but they were probably taken in autumn. Hildebrand and Schroeder (1928:278) gave a summary of length data on eight collections comprising 118 young-of-the-year taken from September to November 1921 at six localities from the lower Patuxent River to the mouth of Chesapeake Bay (also reprinted by Pearson, 1929:144). Their fish, which ranged in size as follows: September—20-42; October—26-53; and November—39-90 mm, were generally similar in size range to the *Sciaenops* for the same months given in Table 1: September—20-50; October—20-75; and November—30-80 mm. Fig. 1 shows a frequency distribution of a typical collection of these young-of-the-year red drum. Pearson (1929:142), in a concerted study of this species on the Texas coast, collected young ranging from 5 to 60 mm long in shallow

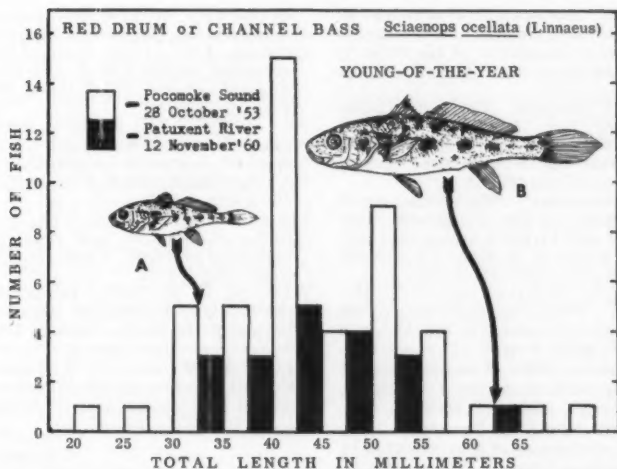


Fig. 1.—Size frequency distribution of young-of-the-year red drum, *Sciaenops ocellata*, from Chesapeake Bay. The drawings show the appearance and stage of development of two of the red drum taken on 12 November 1960: A—30 mm; and B—61 mm total length. Drawing by Alice J. Mansueti.

water during October and November. Gunter (1945:68) also collected specimens ranging from 17 to 58 mm long in the same area with a minnow seine during the same months. As a result of Pearson's collections, Hildebrand and Cable (1934:47-51) were able to present key characters for distinguishing *Sciaenops* between 5-6, 8-10, 15-20, and 30-35 mm from many other species of sciaenids. Mansueti and Schelteema (1953:6, Table 15) provided some additional size data on young-of-the-year which is also given in Table 1 (localities F, G and H). In none of the citations given above is there any indication that the fish were taken anywhere except in shoal water.

The time of first spawning is still unclear (Welsh and Breder, 1924: 184—September to late fall or early winter; Hildebrand and Schroeder, 1928: 278—quoted Welsh and Breder; Pearson, 1929:142-4—chiefly in October, extending from end of September and ending about mid-November; and Gunter, 1945:68—last of September to first half of November). Pearson (1929:144) acknowledged that *Sciaenops* apparently spawns somewhat earlier off Chesapeake Bay than along the Texas coast, and this generalization still seems true. The smallest young taken in the Chesapeake Bay are slightly less than one inch long during mid-September. It can be inferred from indirect evidence that the time necessary for a prolarvae to grow an inch long would be about a month, allowing for the differential effects of season, temperature, and species-specific growth rate. Nothing is known about the rate of growth of *Sciaenops* during this larval period, but two sources of data allow for this inference: (a) rate of larval growth of closely related species; and (b) time required for plank-

tonic transport from the ocean to the upper estuary. While data on the autumn rate of growth of fish larvae and young are not available, Hildebrand and Cable (1934:64, 108) presented a graphic picture of larval growth of the southern kingfish, *Menticirrhus americanus*, and weakfish, *Cynoscion regalis*, during spring and summer months in the North Carolina latitudes. Growth was slow at first, a period of roughly about one or two months was required before the larvae attained an inch in length. The conditions, of course, are reversed in autumn spawning species, where growth may be rapid at first, decelerating as fall and winter approaches. The hydrographic evidence suggests that roughly one to three weeks might be required to bring larvae from the ocean to the mid-Chesapeake. Assuming the deep water upstream velocities of 0.1 to 0.4 knots in Chesapeake Bay and certain tributaries (Pritchard, 1951:375; and Haven, 1957:96), it would take about 10 to 20 days for drifting larvae *Sciaenops* to be carried a distance of about 100 miles from the mouth of the bay to the Patuxent River. These points suggest that some early spawning begins off the mid- and south-Atlantic region in mid-August and early September, with the bulk of the hatch being produced in late September and October. There is little clear evidence to show when spawning ceases. The eggs and early prolarvae of this species have not been observed or described.

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Recent Additions to the Upper Chesapeake Bay Fish Fauna¹

ABSTRACT

Nineteen species of fish new or of recent occurrence (1957-60) to the fish fauna of the upper portion of Chesapeake Bay, Maryland, are presented. Abundance, size, lateness of occurrence, and/or ecological conditions are discussed.

Uhler and Lugger (1876:67-176), Lugger (1877: 57-94; 1878:107-25), Hildebrand and Schroeder (1928:1-366), Truitt, Bean and Fowler (1929:1-120), and Massmann (1957:156-57; 1960:70) have "generally" noted the presence of various fishes from the lower portion of Chesapeake Bay, especially near the mouth or those areas adjacent to Capes Henry or Charles. It is the purpose of this article to call attention to 19 species which have been recorded, in recent years (1957-60), from that area north of 37°50'N, hereinafter referred to as the upper bay and essentially within Maryland. Unless stated all measurements are total lengths.

Branchiostoma caribaeum Sundevall, lancelet. This small species was reported from Sewalls' Point and the eastern shore of the lower bay by Rice (1880:1), Andrews (1893:238-40), Hubbs (1922: 8-9), Pratt (1935:754) and Bigelow and Schroeder (1948:14). One 183 mm specimen was dredged up from 20 feet of water 200 feet east of Point Look-out lighthouse and the mouth of the Potomac River, November 10, 1959. The myomere count was

37 + 14 + 10 = 61 and agrees well with that cited by the above authors.

Squatina dumerili LeSueur, Atlantic angel shark. Truitt, Bean and Fowler (1929:28) list this species from Worcester County waters, probably ocean side where this author has seen many specimens up to four feet long taken by the trawlers out of Ocean City, Maryland. The only upper bay specimen known is a 34 pound, 46 inch specimen captured off Broad Creek in Pocomoke Sound August 22, 1958.

Myliobatis freminvillei LeSueur, bullnose ray. Uhler and Lugger (1876:157) and Truitt, Bean and Fowler (1929:28) note the entry of this species into the mouth of Chesapeake Bay. A young male 9-9/16 inches wide (body length 6 inches, tail length 13½ inches) was captured alive in a dip net in the Patuxent River at Solomons August 27, 1957. The water temperature and salinity on this date was 24.5°C and 15.4 ‰, respectively. This specimen lived in a 60 gallon aerated aquarium in a furnace room for two months. Its death was believed hastened by a sudden temperature increase of water temperature up to 85°F. (29.4°C.). Soft-shelled clams, *Mya arenaria*, were force-fed into the specimen when no signs of normal feeding were observed.

Opisthonema oglinum (LeSueur), Atlantic thread herring. This species occurred so abundantly during June and especially July 1957 in the northern part of Chesapeake Bay (up to the bay bridge) that pound nets and haul seines were choked with fish which ranged 4-6 inches in length. Several

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similar sized specimens were taken August 8, 1957, off Chesapeake Beach, Maryland, still fishing with blood worms during a fishing fair contest. Additional records are lacking for subsequent years.

Synodus foetens (Linnaeus), inshore lizardfish. Known from the Potomac River (Uhler and Lugger 1876:130) and Chesapeake Beach (Hildebrand and Schroeder (1928:102). Numerous 10-12 inch lizardfish were captured August 8, 1957, during the Chesapeake Beach, Maryland, Fishing Fair when they struck viciously on trolled "buck tails." A number of specimens were recorded that same year from the bay bridge south to the Maryland-Virginia state line and most of the lower tributaries therein. Another surge of lizardfishes was found in the upper bay in 1959 during the months of July and especially August, passing as far up the Patuxent River as Benedict, Maryland, and the Choptank River as far as Cambridge, Maryland. A few 12 inch specimens were captured in the upper bay in August and September 1960 north to Solomons, Maryland.

Alectis crinitus (Mitchill), African pompano. Two specimens have been captured to date in the upper bay. A 10½ inch specimen was caught while trolling in 60 feet of water off Punch Island, Dorchester County, September 20, 1959, while a 10½ inch specimen was caught on the surface one mile offshore and 1½ miles southeast of Long Beach, Calvert County, November 7, 1960. The latter was among a school of striped bass, *Morone saxatilis*, and so sluggish that it was possible to take it up with a dip net. The approximate water temperature and salinity was 53°F. (18°C.) and 15.2 ‰.

Caranx crysos (Mitchill), blue runner. Lugger (1877:76) and Truitt, Bean and Fowler (1929:69) list this species from the lower bay. Schwartz (1958:21) comments on the occurrence of young (5½-6 inches) jacks in deep (80 feet) water of the upper bay in November of 1958. Additional young specimens of the size range cited above were caught while trolling August 6, 1958, on crab claws as bait just south of Cedar Point, St. Mary's County, and while pound netting at Flag Pond (Chesapeake Bay, Calvert County). Pound nets at West River (Anne Arundel County) accounted for 6-7 inch specimens as late as September 17, 1958.

Selar crumenophthalmus (Bloch), bigeye scad. Two specimens 6½ (156.3 mm) and 6¾ (168.6 mm) inches long were taken in a pound net set at Flag Pond August 15, 1958.

Selene vomer (Linnaeus), lookdown. This species has been reported off the mouth of the Potomac River by Uhler and Lugger (1876:94), Hildebrand and Schroeder (1928:226) and Truitt, Bean and Fowler (1929:70). A 4¼ inch specimen was taken at the Flag Pond pound net July 4, 1959. Another was similarly caught near Oxford, Talbot County, Maryland, July 7, 1959.

Vomer setapinnis (Mitchill), Atlantic moonfish. Recorded by the capture of a 4¾ inch specimen in the Flag Pond pound net July 4, 1959.

Orthopristis chrysopterus (Linnaeus), pigfish.

This species was previously known in the upper bay from a record at Love Point (Kent Island, Kent County, Maryland) (Hildebrand and Schroeder, 1928:259). A 10½ inch specimen was captured in a pound net October 13, 1958, set at Kenwood Beach, Calvert County. The water temperature and salinity for this late date capture were 17.6°C. and 13.9 ‰, respectively.

Euthynnus alletteratus (Rafinesque), little tuna. Massmann (1957:157) records two specimens 620 and 660 mm standard length from pound nets in the lower bay at the mouth of the York River. This species was sighted on the middle grounds off the mouth of the Potomac River in late August and off Barren Island (Dorchester County), Maryland, during the 1st-15th of September 1960. A pound net off Plum Point (Calvert County) accounted for an 18 inch specimen October 1, 1960, while the pound net just inside the Potomac River and a few hundred feet from the Point Lookout light caught one 15 pound fish October 15, 1960. Fifteen additional specimens (totalling 128 pounds) were taken at the latter locality October 22, 1960. The first hook and line catch was of a 32 inch, 18 pound fish when trolling near Sharps Island and Stone Rock (Talbot County) October 22, 1960. A school of these tuna remained in an area 3-4 miles long and 3 miles wide, 2 miles south of the Point Lookout light until November 1, 1960, and provided excellent trolling sport fishing. During this period, these fish could be caught from the surface or to a depth of 35 feet as they were feeding on menhaden, *Brevoortia tyrannus*.

Astroscopeus guttatus Abbott, northern stargazer. Another species cited from the lower bay (Uhler and Lugger 1876:83; Truitt, Bean and Fowler, 1929:108). This species has been recorded only once previously (Mansueti, 1955:2). An 8 inch specimen was caught while trolling at Cedar Point, St. Mary's County, Maryland. A 10½ inch specimen was trolled up from the same locality October 2, 1960, while fishing on the bottom with a "buck tail" in 25 feet of water. The water temperature and salinity conditions were approximately 22.1°C. and 12.7 ‰.

Echeneis naucratus Linnaeus, shark sucker. Uhler and Lugger (1876:118) and Truitt, Bean and Fowler (1929:49) note that this species occasionally frequents Chesapeake Bay. A 15 inch specimen was caught in the Patuxent River at the Chesapeake Biological Laboratory pier, Solomons, Maryland, by hook and line using blood worms as bait on July 18, 1957, (water temperature 26.6°C., salinity 13.7 ‰). A bull shark, *Carcharhinus leucas*, which was captured July 30th of that year a few miles further up the Patuxent River was possibly the agent on which this specimen entered the area. A second specimen 12½ inches long was caught on hook and line July 22, 1957, one mile south of the bay bridge in Chesapeake Bay while trolling for striped bass, *Morone saxatilis*. An 18 inch fish was taken by this author from a cownose ray, *Rhinoptera bonasus*, caught in a pound net at Flag Pond July 23, 1958, where the water temperature and

salinity was 26.0°C. and 9.2 ‰, respectively. Prior to these records several similar sized fish were caught in the Patuxent River July 25 and 31, 1953, and August 20, 1954.

Alutera schoepfi (Walbaum), orange filefish. This species is known from St. Mary's River (Truitt, Bean and Fowler 1929:101; Hildebrand and Schroeder 1928:345) and mainly from the lower bay (Lugger 1877:67; Massmann 1960:70). Specimens were obtained following explosive tests near buoy "16-D" just west of Barren Island and 6 miles east of Solomons. Charges of 1,200-10,000 pounds set in 80-120 feet of water produced 18-22½ inch specimens on July 29 and 31 and August 1 and 8, 1957. A sluggish 14 inch specimen was dip netted from the Patuxent River "T-pier" November 12, 1959, when the water temperature and salinity were 12.8°C. and 16.4 ‰, respectively.

Lagocephalus laevigatus (Linnaeus), smooth puffer. This is another species that Uhler and Lugger (1876:73) and Truitt, Bean and Fowler (1929:102) cite from the southern part of the bay. Three specimens are known from the upper bay. A six pound, 20¼ inch specimen was caught one mile south of the bay bridge October 8, 1959. A 26¾ inch, 10 pound fish was caught on the bottom in 10 feet of water at Hog Point (south shore and mouth of the Patuxent River) at night on trolled "cut" spot October 8, 1959, while a six pound specimen is known from a pound net off Strafford Cliffs October 26, 1959.

Chilomycterus schoepfi (Walbaum), striped burrfish. Numerous 1½ inch yellow-green young of this species were collected during the period July 25-August 5, 1957, while beach haul seining along the northeast shore of the Patuxent River over sandy bottoms. Adults 4-6 inches long have been trawled up from 30 feet of water and caught on hook and line in the Patuxent River as far upstream as Point Patience during the same period.

It is a pleasure to thank Walter and Russell Duncan whose pound nets were set at Flag Pond and the Higgins Brothers whose nets were at Kenwood and Calvert Beaches for permitting me to work with them and to obtain the many specimens

cited caught in their nets; R. Langley and E. Jones of Solomons and E. Buckley and A. Jones of Aquasco, Maryland, for their enthusiasm and regard for the "odd" specimens.

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A Notable Range Extension of the Southern Drill, *Thais haemastoma floridana*, into Chincoteague Bay¹

ABSTRACT

Live specimens of the southern drill have recently been collected in the Chincoteague Bay area of Maryland and Virginia. This extends its known northern limit some 150 miles beyond its previously recognized range. Evidence from dredged shells, however, indicates that the species

was established at a much earlier date in the Maryland part of Chincoteague Bay, perhaps before the closure of the Green Run inlet in 1883.

This note presents further information on the range extension of the southern drill, or Florida rock-shell, *Thais haemastoma floridana* Conrad, into Chincoteague Bay, Virginia (Sieling, 1956:1), and presents evidence of its apparent long-time occurrence in the Maryland part of the Bay. In

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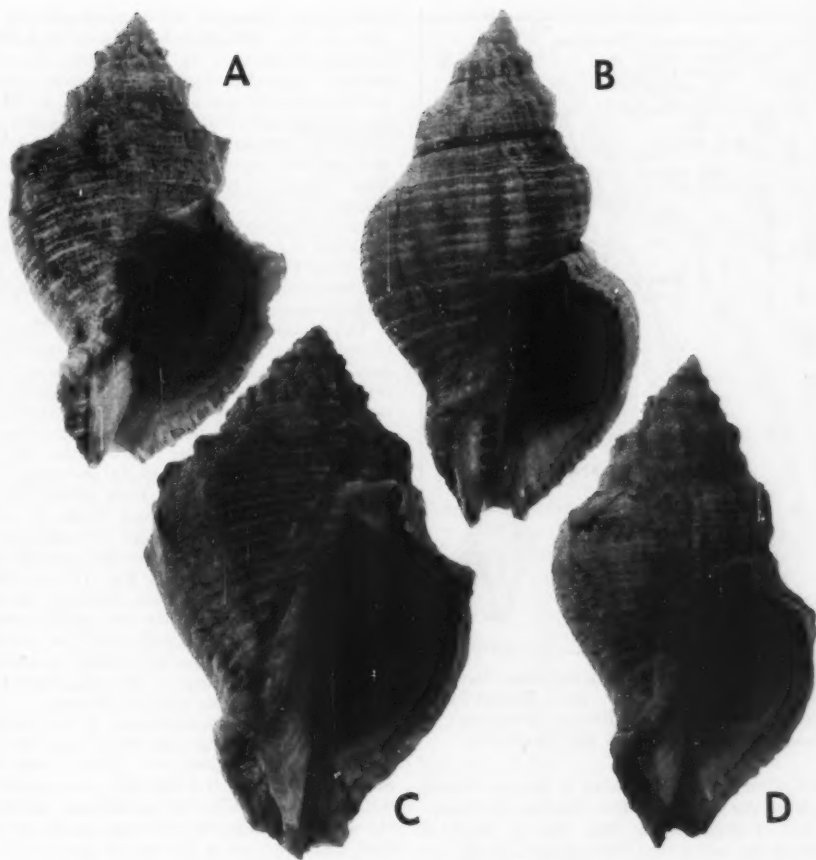


Fig. 1.—Comparison of the southern drill, *Thais haemastoma floridana*, from Chincoteague Bay with specimens from the Gulf of Mexico region: A and B. Females from Barataria Bay, Louisiana, USNM 568834, V, Schlechter, coll. 1942; C. Hog Island Bay, Virginia, USNM 618840, F. W. Sieling, coll. 1955; and D. Hog Island Bay, Va., F. W. Sieling, coll. 1956.

September, 1955, this species (Fig. 1) was found at Hog Island Bay, Virginia, immediately inside its inlet (Fig. 2) in an oyster drill trap on an oyster bed. The trapping program was designed to catch the much smaller species of oyster drill, *Urosalpinx cinerea*, which occurs abundantly in the region. During the spring of 1956 and also in 1957, several additional live specimens of *Thais* were taken. The specimens illustrated in Fig. 1 from Hog Island Bay, for example, were taken as follows: Fig. 1C. Willis Wharf, Northumberland County, Virginia, September 15, 1955, from a trap in eight feet of water; and Fig. 1D. Hog Island Bay, Virginia, May 28, 1956, from a trap in 10 feet of water.

The most northern location in which *Thais* was taken in Chincoteague Bay was between George

Island Landing and Girdle Tree Landing, Worcester County, Maryland, (USNM 618841) in a hard-shell clam dredge on October 20, 1955. Since drill-trapping is not practiced in Maryland, trapped examples of *Thais* are lacking. The most northern record from Virginia is from the lower end of Chincoteague Bay at Tom's Cove, where there are many oyster beds just inside the inlet. Although the author observed the specimen from this location in 1957, it has been retained by the waterman who found it. All of the specimens were captured in salinities ranging between 25 and 34 ‰, and the habitat rarely exhibits salinities below 20 ‰ at any time of the year. These areas are all near the inlets from the Atlantic Ocean, hence salinities remain relatively high throughout the year.

The discovery, in 1957 and 1958, of several old

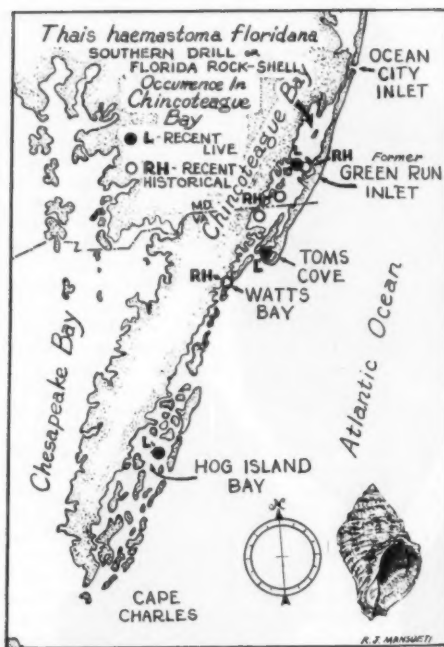


Fig. 2.—Records of *Thais haemastoma floridana* based on specimens taken alive (L = Recent Live) and as old shells (RH = Recent Historical) in Chincoteague Bay, Maryland and Virginia.

shells of *Thais* from the vicinity of the now-closed entrance of the old Green Run Inlet in the Maryland part of Chincoteague Bay (Fig. 2) forced a revision of the belief that the species has only recently immigrated to Chincoteague Bay. These old shells were compared with recent *Thais* in the mollusk collections of the U. S. National Museum (USNM), and were positively identified as *Thais haemastoma floridana* by Dr. H. A. Rehder and later by Dr. J. P. E. Morrison. These specimens were also found to be indistinguishable from specimens taken in the Gulf of Mexico area. Thus, these old shells were classified as recent historical (RH) specimens, hence could have occurred in the bay from 80 to 110 years ago when the Green Run Inlet was open and navigable (Fig. 2). The lack of similar recent historical specimens from the only other entrance, Chincoteague Inlet, suggests that perhaps the major ingress was then restricted to the old Green Run Inlet, or that the recently changing contours at the Chincoteague Inlet have obscured areas where such shells may have occurred. Periods of mild winters which were known to have occurred about a century ago would have insured survival for this essentially southern species and would have allowed them to overwinter successfully. Possibly the establishment was not

firm in the beginning but through natural selection, certain individuals may have been able to become acclimatized to the locality. It is interesting to note that the intensive survey, restricted to Chincoteague Island and vicinity, by Henderson and Bartsch (1914) failed to uncover this species. It is possible that survival was low or absent at that time because of unusually severe winters. Also, Andrews (1951:8) did not record it from Chesapeake Bay. The collection of all the specimens in Chincoteague Bay extends the known upper limit of its range at least 150 miles northward; i.e., from Pea Island inside Oregon Inlet, in the northern end of Pamlico Sound, North Carolina, to Chincoteague Bay, Maryland.

The striking similarities between *Thais* from Chincoteague Bay and Louisiana waters can be seen in Fig. 1. The rough knobbed type and the smooth type exhibited in southern specimens are both found in those from the Maryland-Virginia area. Note that both have the same fluted margins to the shell. Gradations between the two types have been observed throughout the range of the animal. The shells on Fig. 1 are arranged so that the two types, smoothed and knobbed, may be compared easily: Fig. 1A and 1C, although from widely separated areas, exhibit the generally rough-knobbed appearance, while Fig. 1B and 1D exhibit the smooth appearance. Although specimens taken in Chincoteague Bay are small in number (Table 1), they exhibit wide variation among individuals, as is the case with many in the U. S. National Museum taken at the same time from a single locality in other parts of its range.

Table 1 gives measurements of the Maryland and Virginia specimens, and when these were compared with data given by Clench (1947:76-8), Smith (1937), Abbott (1954:213), and others, they were found to overlap the normal size variation of the species throughout its range, especially in the Gulf area. Also, while the size of sample for measurements of live specimens from Chincoteague Bay is small, a comparison of average measurements with recent historical specimens from the same area indicates that they essentially are from the same population.

The potential implications of an established population in Chincoteague Bay waters can be estimated from the behavior and economic importance of *Thais* in more southern waters. As a carnivorous gastropod in the Gulf States, it is the most destructive predator on oyster beds in tide-water (Butler, 1950). This species is found in great numbers in estuaries and coastal bays, and appears to thrive successfully on almost any type of bottom. It apparently has a wide tolerance to salinity changes, pH levels, and low oxygen conditions. Biologically speaking, it is a very successful animal, hence its populations in Chincoteague Bay must be carefully observed in the future. If it were to increase its numbers enormously because of favorable environmental or meteorological conditions, *Thais* could create oyster predation problems as serious as those currently experienced

TABLE 1.—Measurements of live and recent historical specimens of the southern drill, *Thais haemastoma floridana*, from Chincoteague Bay.

Number	Locality	Date	Total Length	Width	Aperture	Collector
A. Recent Live Specimens (L) ¹						
USNM 618841	Between George Island and Girdle tree Landing, Worcester Co., Md.	20/X/55	80	49	21 × 37	F. Sieling
USNM 618844	Hog Island Bay, Va.	"	84	50	22 × 43	"
USNM 618851	Hog Island Bay, Va.	"	54	30	14 × 23	"
No Number assigned as yet	Hog Island Bay, Va.	28/V/56	77	41	18 × 37	"
FS RL 1	Chincoteague Inlet, Va.	—/VIII/57	76	46	16 × 26	"
Mean			74.2	43.2	33.2 × 18.2	
Range			54-84	30-50		
B. Recent Historical Specimens (RH) ¹						
FS RH 1	Chincoteague Bay, Md.	—/XII/57	83	50	18 × 33	F. Sieling
FS RH 2	" " "	"	93	54	21 × 41	"
FS RH 3	" " "	"	75	45	19 × 33	"
FS RH 4	" " "	"	81	45	19 × 33	"
FS RH 5	" " "	"	83	46	20 × 36	"
FS RH 6	" " "	"	72	40	18 × 31	"
FS RH 7	" " "	"	68	37	16 × 26	G. Griffith
FS RH 8	" " "	"	71	39	17 × 31	F. Sieling
FS RH 9	" " "	"	50	33	14 × 22	"
FS RH 10	" " "	"	56	33	14 × 24	"
FS RH 11	" " "	"	45	29	12 × 22	"
FS RH 12	" " "	"	77	45	22 × 34	G. Griffith
RF RH 13	Watts Bay, Va.	—/XI/58	93	56	25 × 41	R. Kelly
Mean			72.8	42.5	31.3 × 18.1	
Range			45-93	29-56		

¹ Abbreviations: USNM—U.S. National Museum; FS/RL—Fred Sieling, Recent Live; FS/RH—Fred Sieling, Recent Historical.

with the oyster drills, *Urosalpinx* and *Eupleura*, in Chincoteague Bay. Also, this species could easily extend its range rapidly since the larvae are pelagic, although present data indicates that water temperature may be the primary and formidable limiting factor.

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THE
HISTORY
OF
THE
CITY
OF
NEW
YORK
FROM
1624
TO
1898
BY
JOHN
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AND
JAMES
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